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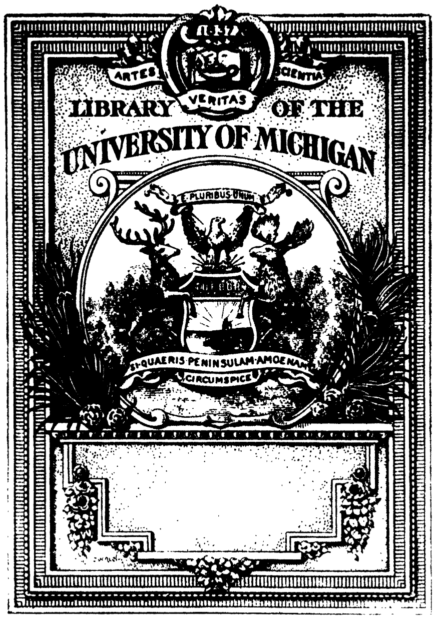

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THE PHILIPPINE

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A. GENERAL SCIENCE

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THE TERPENE OILS OF MANILA ELEMI.

By A. M. CLOVER.

(*From the Chemical Laboratory, Bureau of Science.*)

INTRODUCTION.

The name *elemi* is commonly applied to a number of resinous products obtained from different countries and having a different botanical origin. The species from which most of the varieties are derived is unknown, but there appears to be little doubt but that they are all to be referred to the general order of *Burseraceæ*.[1] From Mexico, Central America, Brazil, Guyana, Africa, and the Philipine Islands, products known as *elemi* find their way into European markets. A common characteristic of the different varieties is that they all contain a good proportion of volatile oil. Further, from the incomplete data to be found in the literature, it appears that nearly all, if not all, yield a good proportion of crystalline substances when they are treated with alcohol, in which the crystalline portion is only sparingly soluble.

According to Gildemeister and Hoffman,[2] *elemi* was known in Europe in the fifteenth century and used for medicinal purposes. It is still used in Europe medicinally in the preparation of ointments and plasters and is also said by different authors to have a limited use in the manufacture of lacs and varnishes for imparting toughness to these products. Wiesner[3] states that it has recently come into use in the preparation of lithographic inks. The total consumption of the product is not large, and the greater part of the world's supply is at present derived from the Philippine Islands, this product being commonly known as Manila *elemi.*

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[1] Merrill: The Source of Manila Elemi, *Publ. Bur. Govt. Labs.*, Manila, (1905), **29**, 51-55.

[2] Die Aertherischen Oele. Berlin (1899), 642.

Manila elemi.—The resin is derived from the species *Canarium luzonicum.* This fact has positively been determined from an abundance of botanical material obtained by myself and reliable collectors and submitted to Mr. Merrill, the botanist of the Bureau of Science. A. Tschirch and J. Cremer[4] have recently arrived at the definite conclusion that Manila *elemi* is derived from *Canarian commune* L. Their conclusion is the result of an examination of samples of Manila *elemi* and resin obtained by one of the authors in India from the species *Canarium commune,* and is based upon a comparison of the general properties of the two products as well as of the crystalline substances isolated therefrom. So far as their work went they were unable to note any differences between the two products.

The tree *Canarium luzonicum* is quite widely distributed in the Philippine Islands and is known by the Tagalogs as *pili.* There are two closely related species designated as *pili. Canarium luzonicum* bears a small nut, while the other, which has been identified by Mr. Merrill as *Canarium pachyphyllum,* bears a much larger one, produces resin in only very small amounts, and is never used by the natives as a source of the latter.

Pili resin is commonly known by the Spanish term *brea* which is applied by the natives indiscriminately to all similar products. The resin is obtained by removing a narrow strip of bark horizontally about the trunk of the tree in four or five different places. A thin, transparent fluid soon appears about the exposed part and in time becomes somewhat viscous and opaque. The amount of resin increases for a month or so, gradually falling several inches below the cut and in time taking on the appearance of a cataract. If the resin is not frequently removed it hardens on the outside and generally takes on a yellowish color. I have seen several good-sized trees upon which had accumulated at least 10 pounds of resin, probably within a few months. For commercial purposes the resin is required to be as soft, clean, and colorless as possible, so with this in view it is carefully removed from the tree at definite intervals and not allowed to accumulate. When a tree is continuously used for resin it is customary about once a year to remove the bark for a couple of inches above the last cut. Many trees are to be found which have evidently been long employed in this manner and which give evidence of this gradual removal of the bark for several feet up and down the trunk. The resin finds considerable use among the natives as an illuminant, for which purpose it is rolled in a palm leaf, or better, in the fibrous part of the trunk of the young coconut tree. For such purposes it behaves very similarly to pine pitch, and a large torch of it, used especially by fishermen, gives a light which can be seen at a great distance and which burns for many hours.

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[3] Die Rohstoffe des Pflanzenreiches. Leipzig (1903), **1**, 242.

[4] *Arch d. phar.* (1902), **240**, 313.

As ordinarily gathered for commerce, the resin is soft, sticky, and opaque, has a slightly yellow color, and a very agreeable odor. It has a spicy, somewhat bitter taste. If left exposed to the air for some time, it gradually hardens throughout and finally becomes brittle. The resin dissolves readily and completely in ether, chloroform, and benzene, except for the separation of a small amount of water which it contains and also a very small amount of a white, granular substance. In acetic ester, acetone, ligroïn, methyl and ethyl alcohol it does not dissolve completely unless sufficient solvent is used. With these solvents a white, crystalline residue remains which, with the use of alcohol in limited quantity, amounts to about 25 per cent of the total. This insoluble, crystalline portion of *elemi* resin has been the subject of considerable study and will be referred to again briefly in this paper. Very soft Manila *elemi* contains a considerable amount of water, less than 5 per cent however, while that which has collected on the tree for a length of time contains very little.

Elemi oil.—The volatile portion of *elemi* resin designated as *elemi* oil has long been known to chemists. It is generally obtained by steam distillation of the resin. Gildemeister and Hoffman state that the commercial product is prepared from Manila *elemi* exclusively, although in most cases where this oil has been used in chemical investigation there seems to be much doubt as to its origin. At present it has little use.

The oil was first studied by Stenhouse,[5] who prepared it by distilling the hard resin with steam. The variety of resin employed is not given. He obtained a yield of only 3.5 per cent of oil and gives its boiling point as 166° and its specific gravity as 0.852 at 24°. His analysis showed the oil to be oxygen-free. Deville[6] found that the percentage of oil obtained from the resin depended upon whether it was fresh and soft or had become hardened by long contact with the air. From resin of good quality he obtained 13 per cent of oil. He describes the oil as having a specific gravity of 0.849 at 11°, an index of refraction of 1.4719 at 14°, and a rotation of —90°.5. The product boiled very constantly at 174° and analysis showed it to contain no oxygen. By treating the oil with hydrochloric acid gas he obtained a crystalline substance which was optically inactive but concerning which he obtained no further data. No statement is made concerning the origin of the resin which he used.

In 1888, Wallach[7] detected phellandrene in *elemi* oil but does not mention the source of the oil. Shortly afterwards Wallach[8] studied the oil more carefully, and in this case also does not state the origin of the oil with which he worked. It was dextro-rotatory and showed a specific gravity of 0.900 and an index of refraction of 1.48592 at 20°. After fractionation, a good quantity of the nitrite of dextro-phellandrene was obtained from that portion boiling below 175°. In the portion boiling from 175° to 180° he isolated a large amount of dipentene tetrabromide by treating it with bromine in acetic acid. He recommends the use of the oil for the preparation of dipentene derivatives. He points out that the crystalline hydrochloride obtained by Deville was dipentene dihydrochloride. Wallach detected no other substances in the oil, but states that it contained a good portion of higher-boiling matter which split off water during the distillation. During the rectification of the oil he frequently noted the appearance of fine, needle-like crystals. These he connected with the crystalline constituents of *elemi*. These crystals will be referred to later in connection with my own results.

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[5] *Ann. Chem.* (*Liebig*) (1840), **35**, 304.
[6] *Ibid.* (1849), **71**, 352.
[7] *Ibid.* (1888), **246**, 233.
[8] *Ibid.* (1889), **252**, 102.

From the data given by Wallach it appears that the oil with which he worked was distilled from the resin at a temperature much above 100°, for it will be shown later that Manila *elemi* contains a good proportion of high-boiling, oxygen-containing oil, having a higher specific gravity and refractive index than the low-boiling terpene-containing portion. This high-boiling oil is not removed from the resin except at higher temperatures. The oils worked with by Stenhouse and Deville, as they are described, contained none of this high-boiling oil and were probably removed from the resin at 100°.

Schimmel & Co., in their semiannual report of October, 1896, publish some observations concerning the higher-boiling portions of *elemi* oil. They isolated a product most of which pased over from 160° to 161° at 10 millimeters. At ordinary pressure it boiled from 279° to 280°. It was optically inactive and had a specific gravity of 1.043 at 15°. They did not make an analysis. The April, 1897, report of the same firm gives the folowing data concerning *elemi* oil as determined by them:

Yield of oil from raw material, 15 to 30 per cent.
Specific gravity at 15°, 0.87 to 0.91.
Optical rotation, +45°.

Tschirch and Cremer[9] have distilled Manila *elemi* as well as other varieties of *elemi* with steam and obtained oils, but the very meager data which they give do not enable one to decide what differences, if any, exist in the different oils. The oil from Manila *elemi* constituted nearly 20 per cent of the original, soft resin. The major portion of it boiled from 170° to 175°, this distillate showing the remarkably high specific gravity of 0.955, which figure seems almost incredible. Beyond 175° a thicker oil passed over. The fraction from 175° to 210° deposited white, needle-like crystals on standing; these crystals melted at 170°.

EXPERIMENTAL.

The following work concerns only the volatile constituents of Manila *elemi*; that portion consisting of terpenes and sesquiterpenes and their derivatives, which can be removed by distillation from the resin without decomposition of the latter. In a preliminary examination of a sample of *elemi* sent to the Bureau of Science from outside of Manila, it was found that the low-boiling constituent of the oil obtained therefrom was phellandrene, boiling *in vacuo* almost completely within one degree and pure so far as it was possible to determine. To be able to obtain this substance so pure and in considerable quantity would be of especial advantage in studying the constitution of this terpene and it was decided to take up this problem. It was thought that the oil employed by previous workers, which evidently was only partly phellandrene, had become altered on account of the age of the resin or was derived from a different variety of resin. A good quality of commercial *elemi* was obtained from a dealer in Manila and the oil removed from a portion of this by steam. When redistilled twice *in vacuo* it boiled from 88° to 90° at 50 millimeters and from 173° to 175° at ordinary pressure. The optical rotation was as follows:[10] $\alpha^{30}_{D} = -55^\circ.2$. Its boiling point was a little higher than that of the previous oil and was not so constant. The oil gave a precipitate of phellandrene nitrite when it was treated with nitrous acid in the cold; on filtering, this product was somewhat gummy. On treatment with bromine in cold acetic acid, a crystalline bromide was obtained which, after recrystallizing, melted at 120°. The oil was evidently not pure phellandrene and appeared to be a mixture of phellandrene and dipentene.

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[9] *Loc. cit.*

A new quantity of *elemi* was then obtained from another dealer and the oil derived from this in the same way as the last, boiled from 92° to 94°.5 at 51 millimeters and from 175° to 177° at ordinary pressure, $\alpha^{30}_{D} = +96^\circ.2$. The oil gave a precipitate of phellandrene nitrite, small in amount. With bromine in acetic acid, a crystalline bromide was obtained which, after recrystallizing, melted at 103° to 104°, and was, accordingly, limonene tetrabromide.

A fresh sample of resin sent from the Province of Tayabas yielded an oil boiling from 80° to 81°.5 at 38 millimeters, accordingly about 3° below the boiling point of limonene, $\alpha^{30}_{D} = +122^\circ$. It gave a heavy precipitate of phellandrene nitrite and no crystalline bromide when treated with bromine in acetic acid. It appeared to be almost, if not quite, pure phellandrene.

Later, two small fresh samples taken from single trees and sent to the laboratory, with botanical material for identification of the species, were examined. The oils were removed and purified as before. One of these gave no phellandrene nitrite but a crystalline bromide having a melting point of 104° to 105° was obtained. The other gave a very heavy precipitate of phellandrene nitrite and no crystalline bromide when treated with bromine in acetic acid. Owing to these results it was thought that the great variation found in the different oils was probably due to a difference in the resin obtained from different trees of the species. In order to study this matter further I decide to collect samples of resin from single trees, for separate examination. Accordingly I went to the Province of Tayabas and from different places in that province I gathered seven samples of from one to two kilos each from *pili* trees differing in size and sex. At the same time leaves taken from these trees were preserved and also fruit where it was possible to obtain it. All the trees appeared to the writer to be of the same species and all the botanical material gathered was assigned by Mr. Merrill to the species already given. The samples were obtained as fresh as possible, considering the fact that the resin must have remained on the trees for a month or so in order to allow of the production of a good-sized mass. The different samples were well wrapped in palm leaves and were all worked up within four months after being gathered. The results developed by their examination not only confirmed what had been suspected in regard to variation, but showed that in the majority of cases, in each individual sample, a definite terpene of the limonene series occurred in a pure condition.

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[10] This form of expression will be used throughout this article to represent the optical rotation in a 10-centimeter tube at the temperature indicated.

In order to obtain larger quantities of these pure terpenes and to extend the results already obtained; also with the hope of isolating one or more of the unknown terpenes of this class, another collecting trip was made and 14 more samples gathered just as in the previous case. All of these latter were worked up within four months after they were collected. As a result of the complete examination of these 21 samples, it has been possible to isolate the terpenes dextro-limonene, dextro-phellandrene, terpinene and terpinolene in a pure condition and to study the behavior of these substances in a number of ways; to render certain the presence of an unknown terpene in several products; to establish regularities in the occurrence of certain mixtures where the terpene product is not homogeneous; to isolate in a pure condition from single samples, two of the constituents of the high-boiling portion of the oil and to show the composition of the mixture which constitutes the high-boiling oil obtained from most samples. The high-boiling oil occurring in *elemi* and which can be most conveniently and completely removed by distillation *in vacuo,* will be seen to be a mixture of at least three substances. Here also a great variation has been found in the different samples but no connection appears to exist between the terpene oil and the corresponding high-boiling one. No connection can be traced between the age or sex of the tree and the constituents of the oil.

The following relates to the method of procedure followed throughout in working with the resin. It is difficult to remove all of the terpene oil by distillation with steam, and very little of the high-boiling portion goes over except at quite an elevated temperature, because of the increasing viscosity of the residue as the oil is removed. It was desired to remove all the terpene oil possible and, in order to prevent any change in the oil, at as low a temperature as could be used. With this end in view it was found much better to distill the resin in a vacuum. It was also found that the high-boiling oil could almost completely be removed from the resin at a pressure varying from 8 to 15 millimeters, with practically no decomposition of the latter. The resin, to introduce it into the distilling flask, was first placed in a beaker and immersed in an oil bath which was kept at a temperature of from 100° to 125°, depending on the ease with which the resin became fluid. The latter was then poured into the flask and the terpene oil distilled over *in vacuo,* the pressure being gradually decreased to 10 or 15 millimeters as the water in the resin passed over; the oil bath was kept between 125° and 150°. The distillation was always made as quickly as possible and in no case was purified terpene oil ever taken from a product which had been heated higher than 150°. Frequently a second distillate was then taken by heating to 200°, at which temperature practically all of the terpene, but only a portion of the high-boiling oil may be removed. If the resin is quite fresh, most of the heavy oil will have passed over before the oil bath reaches 230°, but with an old product it is difficult to maintain a high vacuum, so that the oil bath must be heated to 250°. At this temperature, with fresh material there is very little if any decomposition of the resin, but with that which is old it is possible to remove only a small portion of the high-boiling oil because of the increasing difficulty of maintaining a vacuum as the temperature is raised beyond 200°. In several instances, the purified, high-boiling oils derived from fresh resin at a temperature of 200° were found to be identical with those obtained from the same samples when, in some cases, it was raised as high as 250°; so that it is quite certain that no changes have been brought about in these oils by the high temperature.

Sample I was collected in July near Unisan, Tayabas Province, Luzon, from a relatively young tree about 40 feet in height, having a diameter of about 2 feet near the base. There was no fruit on the tree and its owner said it never had borne any fruit. The resin, of which 1,035 grams were used, was drier than most of the samples.

The first distillate (I,A) was taken at 140° and amounted to 54 grams; the second up to 210° (I,B) amounted to 75 grams; and the third up to 250° (I,C) was 45 grams. The terpene oil was distilled from I,B *in vacuo* and the residue added to I,C. The total terpene oil amounted to 110 grams or 10.6 per cent, and the total high-boiling oil to 64 grams or 6.2 per cent.

I,A was redistilled twice at 54 millimeters; it passed over completely the second time from 93° to 94° (I, A, purified). $\alpha_{D}^{30} = +99°.6$. The oil gave no test for phellandrene and it was found that on the addition of even 1 per cent of an oil known to be nearly pure phellandrene it responded plainly to the test when the solution was kept very cold. In the proportion of 1 to 200 no test could be obtained. With bromine in acetic acid, limonene tetrabromide was obtained; melting point, 104°–105° after recrystallizing twice from alcohol. The oil treated with hydrochloric acid gas in glacial acetic acid, gave a good yield of dipentene dihydrochloride; melting point after recrystallizing from alcohol, 49°–50°. I,A, purified, gave a granular nitrosyl-chloride when treated according to the method of Wallach. The odor of the oil was plainly that of commercial carvene. Metallic sodium when heated with the oil had very little effect on it and after having been distilled from sodium it was found to boil completely at ordinary pressure from 176°.5 to 177°.5. The oil appears to be pure dextro-limonene.

I,C was allowed to stand nearly a year before it was purified. It was redistilled twice at reduced pressure and on the second fractioning the major portion of it was obtained as a yellowish-green product, boiling completely between 165°.5 and 168°.5 at 33 millimeters (I,C, purified).

Sp. gr., $\frac{30}{4}=1.0247$. $\alpha\frac{30}{D}=0$. $n\frac{30}{D}=1.5143$.

Sample II was collected near Atimonan, Tayabas, from a tree having a diameter of about 3 feet near the base and laden with unripe nuts. The sample, of which 815 grams were used, was softer than the previous one.

The first distillate at 125°, amounted to 50 grams (II,A); the second at 210° (II,B), was 123 grams; the third at 250° (II,C), was 30 grams. The terpene oil was distilled from II,B at reduced pressure and the residue added to II,C. The total terpene oil was 132 grams or 16.2 per cent; the high-boiling oil, 71 grams or 8.7 per cent.

II,A was decanted from a small amount of water which collected with it. It was then distilled twice at 36.5 millimeters, passing over the second time almost completely between 82°.5 and 83°.5; three-fourths of it distilled at almost a constant temperature or at most within 0°.25 (II,A, purified). $\alpha\frac{30}{D}=+100°$. The product gave no test for phellandrene With bromine in acetic acid the 104° to 105° melting limonene tetrabromide was obtained and a granular nitrosyl-chloride was also readily formed. It also gave dipentene dihydrochloride melting at 50°. It was distilled from metallic sodium, after which it boiled completely between 176° and 177°, accordingly at a slightly lower temperature than I,A, purified; however, it possessed the same odor and, so far as could be determined, was identical in all other respects.

II,C stood for over a year and was then fractionated twice at reduced pressure, whereupon about one-half of it was obtained as a light, yellowish-green product, boiling completely from 167° to 169°.5 at 35 millimeters (II,C, purified).

Sp. gr., $\frac{30}{4}=0.9522$. $\alpha\frac{30}{D}=-2°.7$. $n\frac{30}{D}=1.4973$.

Sample III, which was quite soft, was obtained from a young tree, smaller than that from which *Sample I* was taken, and standing very close to the latter tree. It was first distilled at 125° for the terpene oil

(III,A) and then at 210° (III,B). In all, 186 grams of distillate were obtained from 900 grams of resin. A further distillation was not made.

III,A was separated from a little water and redistilled three times *in vacuo.* On the third distillation it passed over completely from 89° to 90° at 47 millimeters, $\alpha\frac{30}{D} = +100^\circ.7$. The purified oil had the same odor, boiling point, and optical rotation as the two previous terpene products.

III,B was fractionated once at reduced pressure and the high-boiling portion was preserved for over a year. On redistilling, the major part was obtained as an oil boiling completely from 166°.5 to 169° at 34.5 millimeters (III,B, purified). It was light yellow in color.

Sp. gr., $\frac{30}{4} = 0.9887$, $\alpha\frac{30}{D} = -2^\circ.5$. $n\frac{30}{D} = 1.5055$.

Sample IV was collected near Unisan, Tayabas, from a good-sized tree, nearly 3 feet in diameter near the base. The tree, which at the same time bore no fruit, contained 8 or 10 pounds of soft resin.

One thousand and eighty grams of the sample were distilled, first at 125° (IV,A), then at 210° (IV,B), and finally at 250° (IV,C). The total terpene oil obtained from this sample was 152 grams or 14 per cent, and of high-boiling oil, 145 grams or 13.4 per cent.

IV,A was redistilled twice at 65.5 millimeters and on the second distillation it passed over completely at this pressure from 95°.5 to 97°.5 (IV, A, purified). It was almost optically inactive, $\alpha\frac{30}{D} = +4^\circ$. It gave no test for phellandrene and in a check experiment in which a very small proportion of phellandrene was added to the oil, this was easily detected. No crystalline hydrochloride could be obtained on treatment with hydrochloric acid gas in cold, glacial acetic acid, nor could a crystalline bromide be separated on saturation with bromine, either in acetic acid or in a mixture of amyl alcohol and ether, as has been recommended by Baeyer and Villiger.[11] No solid nitrosyl-chloride could be formed. A good quantity of terpinene nitrite was obtained by using the method recommended by Wallach, the crystals appearing in a short time. When recrystallized from alcohol, this substance melted at 155°, softening a little below that temperature. The oil was distilled over metallic sodium, after which it boiled completely from 174° to 176°. It stood nearly a year in a partially filled, glass-stoppered bottle; it was then redistilled with steam, separated from water and dried over solid caustic potash. Boiling point, 174° to 175°.5. Sp. gr., $\frac{30}{4} = 0.8358$. $\alpha\frac{30}{D} = +4^\circ.3$. $n\frac{30}{D} = 1.4756$. The product still gave a good yield of terpinene nitrite and in all other respects it behaved as it had one year previously. It appears to be almost pure terpinene.

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[11] *Ber. d. chem. Ges.* (1894), **27**, 448.

IV,B was distilled under reduced pressure and the low-boiling portion was refractioned three times under the same conditions. On the third distillation it passed over completely within a range of 2°.5 or 3° and was evidently not so pure a product as that obtained from IV,A, although it gave a good yield of terpinene nitrite. It appears that in this case, as well as with the samples containing phellandrene, there is some alteration in the terpene when it is removed from the resin at higher temperatures.

IV,C stood for nearly a year; it was then redistilled twice *in vacuo* and a product obtained which constituted the major portion of the original material and which passed over completely between 171° and 174° at 39 millimeters (IV,C, purified). It was of a light yellowish-green color and had a mild, pleasant odor. It was much less viscous than any of the high-boiling oils previously isolated and also had a much higher specific gravity. It had very little optical activity. Sp. gr., $\frac{30}{4}=1.0315$. $\alpha\frac{30}{D}=-1°.2$. $n\frac{30}{D}=1.5159$.

Sample V, which was moderately soft, was obtained from a tree standing close to that from which *Sample II* was taken. The tree was laden with unripe nuts.

One thousand grams of the resin were distilled, first at 125° and, excluding 3 or 4 grams of water, the distillate amounted to 61 grams (V,A). The second distillate was taken at 210° and weighed 124 grams (V,B); the third was taken at 250° and was 70 grams (V,C). The total terpene oil was 97 grams or 9.7 per cent and the high-boiling oil was 158 grams or 15.8 per cent.

V,A was separated from water and redistilled twice at 43.5 millimeters. On the second distillation it boiled almost completely from 82°.7 to 84° at this pressure (V,A, purified). Its odor was very pleasant and markedly different from that of any of the terpene products previously obtained, $\alpha\frac{30}{D}=+122°.6$. It yielded a very heavy precipitate of phellandrene nitrite. Neither a solid bromide nor a nitrosyl-chloride could be obtained by the methods ordinarily used. The product appears to be almost pure phellandrene. Its boiling point can be seen to be 3° or 4° below that of the limonene oils and about 2° below that of the terpinene oil. On standing in a partly filled, glass-stoppered bottle, a small amount of a good-sized, colorless, prismatic crystals appeared about the walls of the bottle.

V,B was distilled at reduced pressure, but after the removal of the terpene oil the higher-boiling portion passed over gradually, indicating that only a minor part of it could be isolated as a constant-boiling product. Unfortunately, most of this high-boiling distillate was lost in an accident, but a small quantity of it, on standing, deposited crystals similar to those found in V,A.

Sample VI was obtained near Atimonan, Tayabas. The tree was an unusually large one, being 5 or 6 feet in diameter near the base. A large quantity of soft resin had accumulated from a number of cuts.

The tree bore no nuts and a native familiar with it declared that it had never produced any.

The first distillate (VI,A), obtained at 125° from 1,085 grams of resin, amounted to 140 grams, neglecting a few grams of water; the second (VI,B) was taken to 225° and was 150 grams, and a small additional quantity, 20 grams, was obtained at 245°. The total terpene oil amounted to 183 grams or 16.9 per cent; high-boiling oil, 127 grams or 11.7 per cent.

VI,A was separated from a little water and redistilled twice at 55 millimeters pressure. It passed over completely from 93° to 94° on the second distillation (VI,A, purified). The product possessed the same characteristic odor as that obtained from the previous samples of limonene which had been isolated and its boiling point is also the same, $\alpha_D^{30} = +99°.9$. In rotation, its agreement is seen to be remarkable. Pure limonene tetrabromide was obtained from it and it was also tested thoroughly, just as the oils from *Samples I* and *II* had been, and it showed exactly the same behavior. By comparing the terpene oils obtained from *Samples I, II, III,* and *VI,* especially as to rotation, it appears that when dextro-limonene is encountered in the resin from a single tree, it is found in a pure condition.

VI,B was redistilled once and, after the terpene oil had passed over, the remainder was found to be almost constant boiling, leaving as usual a small amount of a viscous residue. After standing for nearly a year it was redistilled at reduced pressure and most of it obtained as a product showing a nearly constant boiling point (VI,B, purified). Sp. gr., $\frac{30}{4} = 0.9621$, $n_D^{30} = 1.4995$.

Sample VII was obtained near Atimonan, Tayabas, from a tree about 2 feet in diameter, laden with unripe nuts. The sample was a little hardened, but only on the outside.

Nine hundred and sixty grams were distilled, first at 125° yielding 57 grams of distillate, excluding 3 or 4 grams of water (VII,A). A second portion, 128 grams, was taken to 210° (VII,B), and a third, 73 grams, to 250° (VII,C). The total distillate, 258 grams, consisted of about equal parts of terpene oil and heavy oil, or 13.4 per cent of each.

VII,A was redistilled three times at 39 millimeters and on the third distillation passed over from 76°.5 to 79° (VII,A, purified). $\alpha_D^{30} = +114°.7$. The product had the odor of phellandrene, but it also possessed another peculiar odor not noticeable in any of the other terpene products. Its initial boiling point will be noted to be a few degrees lower than that of the sample of presumably pure phellandrene already isolated. The oil gave a precipitate of phellandrene nitrite in good quantity, but many attempts to isolate any other crystalline derivative from it by any of the methods ordinarily employed were unsuccessful. The product was then distilled at ordinary pressure and 2 fractions of equal size were taken—(1) from 167°.5 to 169°; (2) from 169° to 172°. The first fraction showed a rotation of +110°.1 and the second +113°.1. The first fraction was also tested in a number of ways in the hope of isolating a crystalline substance other than phellandrene nitrite, but with negative results. On again distilling, its initial boiling point was lowered only about 0°.5. Both fractions deposited crystals on standing which were similar in appearance to those already noted in the oils derived from the phellandrene-containing samples:

VII,B, was distilled at reduced pressure and after removal of the terpene oil, most of the remainder passed over within a few degrees. It was kept for nearly a year before it was redistilled and it then yielded a product boiling from 165° to 168° at 35 millimeters, this constituting almost two-thirds of the original (VII,B, purified). The purified product was quite viscous, light-yellow in color and of a mild, pleasant odor. Sp. gr., ${}^{30}_{4}=0.9730$. $n{}^{30}_{D}=1.5015$.

VII,C, also stood a year before it was purified. After it had been distilled twice, nearly all of the original substance was obtained as a product boiling from 168° to 171° at 37 millimeters (VII,C, purified). Its boiling point is seen to be a little higher than that of VII,B, purified, but there is very little difference in the other physical properties, so that no marked distinction exists between the two products due to the different temperatures at which they were removed from the resin. Sp. gr., ${}^{30}_{4}=0.9689$. $\alpha{}^{30}_{D}=-2^\circ.5$. $n{}^{30}_{D}=1.5005$.

The work with the following samples was carried out in essentially the same manner as that already detailed, although no particular attention was paid to the amounts of oil obtained. In the interim which occurred at this point of the work, it was found that it was not necessary to use great precaution as to temperature in removing limonene from the resin. Therefore, when a sample was found to contain dextro-limonene, the terpene was removed as completely as possible by heating the resin to 150° or 160°. It was also found that phellandrene suffered a considerable change at a temperature near its boiling point, and it was also thought that terpinene as well would suffer alteration at a higher temperature, especially when it was in contact with the resin. However, it was desirable to remove all of the terpene possible, so that the purified product could be used for further work. In those samples not containing dextro-limonene, the distillation was carried as far as possible at 125° and then the oil bath was heated gradually to 150° and the distillation made as quickly as it could be done. The entire distillate was taken in only two portions, and the high-boiling part was seldom taken beyond a temperature of 235°. In order to obtain the correct data for the physical properties of the terpene oils, they were, unless otherwise stated, first shaken with a dilute solution of potassium hydroxide which freed them from an unpleasant odor often noticed, and then distilled twice *in vacuo,* allowed to stand over night with solid potassium hydroxide and then carefully redistilled, discarding the first 2 or 3 cubic centimeters of the distillate. In a few samples, the high-boiling oil was disregarded entirely. The following samples were all obtained within a radius of a mile or two near the town of Gumaca, Tayabas.

Sample VIII was taken from at tree a little over 2 feet in diameter. The tree contained no fruit. The resin had evidently collected for some time, there being a large amount of it, yellowish and somewhat incrusted, on the tree. The purified terpene oil boiled completely from 95°.3 to 96°.5, at a pressure of 60.5 millimeters, and at ordinary pressure from 176° to 176°.7. $\alpha\frac{30}{D}=+100°.8$. It is evidently pure limonene. Other data concerning the product (VIII,A, purified) will be inserted under the heading of limonene.

The high-boiling oil removed at 225° was redistilled two or three times and less than one-half of it obtained as a product boiling completely from 158° to 162° at 20 millimeters (VIII,B, purified). Sp. gr., $\frac{30}{4}=0.9559$. $\alpha\frac{30}{D}=-2°.4$. $n\frac{30}{D}=1.4985$.

Sample IX was obtained from a tree laden with nuts, of about the same size as that from which *Sample VIII* was taken and standing close to the latter tree. The sample was a large one and somewhat dried out. The purified terpene oil boiled from 176°.5 to 177°.5. $\alpha\frac{30}{D}=+100°.3$ (IX,A, purified). It is evidently pure dextro-limonene but the boiling point is slightly higher than that of the last sample.

This sample of resin was harder than any other which I worked with, the result being that it was impossible to distill off much of the high-boiling oil. As was stated in the introduction, it is difficult so to separate the high-boiling oil from resin which has become somewhat hardened, and almost impossible to isolate a constant-boiling product from the distillate so obtained.

Sample X was taken from a medium-sized tree containing fruit. The resin was fresh and soft. The terpene oil, after the usual purification, boiled completely from 89°.5 to 94°.5 at 65 millimeters, so that, accordingly, the distillation began about 5° below the boiling point of phellandrene, $\alpha\frac{30}{D}=+69°.3$. It gave a heavy precipitate of phellandrene nitrite. It was redistilled at ordinary pressure and the distillate divided into two equal portions: (1) 166°.5 to 168°.5; (2) 168°.5 to 171°.5. The first fraction showed sp. gr., $\frac{30}{4}=0.8356$; $\alpha\frac{30}{D}=+70°.4$; $n\frac{30}{D}=1.4663$, while the second gave sp. gr., $\frac{30}{4}=0.8374$; $\alpha\frac{30}{D}=+64°.6$; $n\frac{30}{D}=1.4680$. The first fraction was redistilled and there was very little lowering of the initial boiling point. The phellandrene nitrite obtained from the oil was recrystallized twice from hot acetic ester and it then melted at 114° to 115°. In its odor and boiling point this oil is very much like that obtained from *Sample VII;* however, in the case of the present sample, there seems to be much more of the lower-boiling terpene present. It appears from the data just given that this terpene is considerably lower than phellandrene in refractive power and specific gravity. As with the oil of *Sample VII*, it was not found possible to obtain any solid derivatives except phellandrene nitrite.

The high-boiling oil from this sample was redistilled. On the second fractionation it showed so small a portion of constant-boiling product that it was totally discarded.

Sample XI.—This sample was small in amount and to obtain enough terpene oil to work with, the latter was completely removed at a temperature of 200°. The oil was not purified *in vacuo* but was redistilled twice at ordinary pressure, passing over the second time mostly from 173° to 178°, $\alpha_D^{30} = -50°.7$. This is the only case in which the lævo-rotatory oil has been obtained from a sample of *elemi*. The oil gave a precipitate of phellandrene nitrite, but the yield was not large. In cold, glacial acetic acid a tetrabromide was separated but a much better yield was obtained in amyl alcohol and ether. When recrystallized twice from alcohol, it showed a melting point of 104° to 105°. The tetrabromide of lævo-limonene in chloroform at 9° and at a concentration of 12.85 per cent gives $[\alpha]_D = -73.45$ as determined by Wallach and Conrady.[12] The amount of pure bromide at hand was not large enough for an accurate estimation, but it was found to be lævo-rotatory and to about the degree just mentioned. A small portion of it was carefully weighed out and mixed with exactly the same amount of pure dextro-limonene tetrabromide. The mixture was dissolved in a small amount of acetic ester and alcohol was then added. On cooling, pure dipentene tetrabromide crystallized out. Melting point 124°. The oil, therefore contains lævo-limonene and phellandrene, the latter being probably dextro-rotatory. That the lævo-limonene was not formed by the action of heat upon the phellandrene will be seen from experiments given under phellandrene.

Sample XII was taken from a medium-sized tree which contained no fruit. The resin was quite soft. The purified terpene oil obtained from this sample showed a boiling point of 176° to 176°.7 at ordinary pressure, $\alpha_D^{30} = +100°.3$ (XII, A, purified). It is evidently pure dextro-limonene. Other data concerning the oil will be inserted under the heading of limonene.

The high-boiling oil from this sample, which had been removed at 240°, was fractionated twice, and the greater part of it was obtained as a product which boiled completely from 167° to 170° at 35 millimeters (XII, B, purified). Sp. gr., $\frac{30}{4} = 0.8677$; $\alpha_D^{30} = +71.6°$. It was light greenish-yellow in color and not so viscous as those oils having a specific gravity around 0.95. It was the only optically active, high-boiling oil isolated from a sample of Manila *elemi*.

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[12] *Ann. Chem.* (*Liebig*) (1889), **252**, 145.

Sample XIII was a large accumulation, somewhat incrusted, taken from a medium-sized tree with no fruit. The purified terpene oil was found to be pure dextro-limonene. Boiling point, 176°.5 to 177°.5; $\alpha\frac{30}{D}=+100°.1$ (XIII,A, purified).

From the high-boiling oil, after distilling three times, a minor portion was isolated which boiled completely within 3°. Sp. gr., $\frac{30}{4}=0.9969$; $n\frac{30}{D}=1.5968$ (XIII,B, purified).

Sample XIV was taken from a medium-sized tree containing fruit. The resin was moderately soft. The purified terpene oil boiled from 91°.5 to 93° at 60 millimeters. Sp. gr., $\frac{30}{4}=0.8322$; $\alpha\frac{30}{D}=+105°1$; $n\frac{30}{D}=1.4694$ (XIV,A, purified). The oil gave a heavy precipitate of phellandrene nitrite which, when recrystallized twice from acetic ester without warming, melted at 119° to 120°. To judge from the boiling point, the oil appears to be nearly pure phellandrene although the rotation is considerably lower than that of the phellandrene from *Sample V.*

The purified heavy oil, which constituted three-fourths of the total, boiled from 167°.5 to 170°.5 at 35 millimeters (XIV,B, purified). Sp. gr., $\frac{30}{4}=0.9482$; $\alpha\frac{30}{D}=-2°$; $n\frac{30}{D}=1.4957$. It was quite viscous and yellow in color.

Sample XV was obtained from a very large tree containing no fruit. It was quite soft. The purified terpene oil boiled from 88° to 91° at 60 millimeters. Sp. gr., $\frac{30}{4}=0.8336$; $\alpha\frac{30}{D}=+112°.7$; $n\frac{30}{D}=1.4678$. The initial boiling point was a little below that of phellandrene and the product was evidently a mixture. It gave a heavy precipitate of phellandrene nitrite which, when purified by recrystallization from acetic ester without warming, melted at 119°.5 to 120°.5. The oil redistilled at ordinary pressure from 169°.3 to 172°. The distillate was divided into two fractions which showed practically the same rotation, a trifle lower than the original. No other crystalline derivatives could be obtained from the oil. The odor is at once suggestive of the oils from *Samples VII* and *X,* which this oil resembles in most respects. During the purification, crystals were noted in the small residue contained in the distilling flask. Crystals also separated from the heavy oil which had been redistilled once and allowed to stand.

Sample XVI was obtained from a good-sized tree about 3½ feet in diameter near the base, and containing no fruit. The resin was fresh and soft. The purified terpene oil boiled completely from 89° to 90°.8 at 56.5 millimeters, most of it going over at almost a constant temperature (XVI,A, purified). $\alpha\frac{30}{D}=+129°.8$; in a 5-centimeter tube the rotation was just one-half of this number. The oil had the characteristic odor of phellandrene and gave a heavy precipitate of the nitrite. A portion distilled at ordinary pressure boiled completely from 172° to 173°.5. This product has the highest rotation of any sample of phellandrene obtained.

The purified, high-boiling oil boiled from 168°.5 to 172° at 37 millimeters on the third distillation, and it constituted most of the unpurified product. Sp. gr. $\frac{30}{4}$=0.9461; $\alpha\frac{30}{D}$=—0.8°; $n\frac{30}{D}$=1.4944 (XVI,B, purified).

Sample XVII.—The purified terpene oil boiled almost completely from 86° to 87°.5 at 48.5 millimeters and therefore, accordingly, a little higher than phellandrene should distill (XVII,A purified). In contained much phellandrene but the rotation as well as the boiling point indicated that some other substance was present, $\alpha\frac{30}{D}$ = + 73°.5; $n\frac{30}{D}$ = 1.4693. A portion of it distilled from 173° to 174°.5 at ordinary pressure. No crystalline bromide could be obtained in acetic acid, nor in ether and amyl alcohol. No limonene could be detected by tests with ethyl nitrite in acetic acid or in ligroin. In preparing phellandrene nitrite, no crystals of terpinene nitrite appeared in the mother-liquor on standing. The crude phellandrene nitrite was dissolved in a small amount of chloroform, filtered and precipitated with ether. Melting point, 114° to 117°. On recrystallizing from acetic ester without warming, it melted at 119°.5 to 121°. On recrystallizing it melted at 120° to 121°. The crude nitrite obtained constituted about 50 per cent of the weight of the original oil. The rotation of the nitrite melting at 119°.5 to 121° was approximately that found by Wallach for pure α-phellandrene α-nitrite obtained from several sources, so that it appears that the low rotation of this sample of phellandrene and the variation observed in the rotation of the other samples obtained, are not to be explained by assuming the presence of varying amounts of lævo-phellandrene. It will be brought out later that the second substance in this oil is lævo-limonene. The high-boiling oil from this sample was redistilled 3 times and a product obtained boiling within 3°. On standing, this oil soon separated an unusually large amount of crystals, identical with those previously observed.

Sample XVIII.—The purified terpene oil boiled completely from 88°.7 to 90°.4 at 54.5 millimeters pressure. It was found to be phellandrene and judging from the boiling point was almost, if not quite, pure, (XVIII,A, purified). The rotation, however, is somewhat lower than that of some of the phellandrene oils. $\alpha\frac{30}{D}$ = +113°.5. On standing for a couple of months the sample contained a small quantity of the familiar crystals.

Most of the high-boiling oil after 3 fractionations was obtained as a product boiling completely from 168°.5 to 172° at 37 millimeters. Just as is XVI,B, purified, it is yellow in color and of high viscosity. Sp. gr., $^{30}_{4}=0.9559$; $\alpha^{30}_{D}=+2°$; $n^{30}_{D}=1.4950$. This oil also deposited a good quantity of crystals on standing.

Sample XIX gave a purified terpene oil boiling from 90° to 91° at 50 millimeters pressure (XIX,A, purified); $\alpha^{30}_{D}=+98°$; $n^{30}_{D}=1.4680$. It is evidently practically pure limonene, although the rotation is a little lower than usual. From the high-boiling oil of this sample it was found impossible to isolate a considerable portion which would show a narrow range in boiling point.

Sample XX.—The purified terpene oil from this sample boiled completely from 81°.7 to 83° at 35.5 millimeters. $\alpha^{30}_{D}=+97°$. The substance appeared to be practically pure limonene, although the rotation is lower than that of any other sample isolated. It gave no test for phellandrene.

Sample XXI proved to be especially interesting. It was small in amount and was a fresh, soft resin when collected, although nearly four months elapsed before it was distilled. The terpene oil on the second distillation passed over almost completely within 1°, the boiling point lying between that of phellandrene and limonene. Its rotation was +4°. Because of its rotation and boiling point, it was at first supposed to be terpinene, but no test for terpinene could be obtained. The oil contained no phellandrene according to notes made at the time it was distilled. There can be no doubt on this point, as the phellandrene nitrite would certainly have been noted in the test for terpinene, the tests always being made in essentially the same manner. On long standing, even after having been inoculated with a crystal of terpinene nitrite, no separation of this substance occurred. On the same day that the test for terpinene was made and when it was found that the terpinene nitrite was not being formed, the oil was treated with bromine in cold acetic acid and a crystalline bromide obtained. This was recrystallized from acetic ester. The crystals did not appear to be those of dipentene tetrabromide, as they melted at about 117° with darkening and effervescence. The substance was recrystallized from alcohol, in which it appeared to be more soluble than dipentene tetrabromide. The crystals were lustrous plates and melted at 116°, with darkening and effervescence. It was noted at the time that these crystals were entirely different from those of dipentene tetrabromide with which I was very familiar and which I rather expected to obtain when the test was made. The substance was certainly the tetrabromide of terpinolene discovered by Wallach[13] in the product formed by the action of sulphuric acid upon American turpentine oil. This body, as given above, is substantially the substance described by Wallach, who also obtained it from the oils resulting from the action of sulphuric acid upon terpine hydrate, terpineol and cineol. Wallach gives 185° to 190° as the boiling point of the fraction yielding the bromide in the first case noted. Baeyer[14] also studied the substance and found that the bromide was best prepared from the oil which resulted from the action of a boiling solution of oxalic acid upon terpineol. By reducing the tetrabromide with zinc dust in cold acetic acid, Baeyer obtained a product which boiled from 183° to 185° and which gave a good yield of the tetrabromide. He found the terpinolene to be rapidly changed by the action of heat.

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[13] *Ann. Chem.* (*Liebig*) (1885), **230**, 262; (1887), **239**, 23.

The oil from this sample as described above was, as usual, shaken out with a dilute solution of caustic potash, then dried over solid caustic potash. It was redistilled on the next day and at 37 millimeters its boiling point was practically constant, at 80° to 81°. The physical constants of the oil were now as follows: sp. gr., $\frac{30}{4}=0.8360$; $\alpha \frac{30}{D}=+1^\circ.7$; $n \frac{30}{D}=1.4701$; boiling point; 173°.5 to 175°.

Up to this time only one day had elapsed since the removal of the oil from the resin. The alteration in its rotation between the second and third distillations was thought to be unusual and with the idea of accelerating any change which was possibly taking place in the oil, a portion of it was heated for 3 hours in a tightly stoppered distilling bulb, immersed in an oil bath at 200°. The product was then distilled over and the range in boiling point appeared to be greater than before heating. The amount of polymerization was very small. *The distillate showed a rotation of —7°.5,* and was found to give a precipitate of *phellandrene* nitrite, although the amount obtained was not large. After the usual treatment of the crude product, namely, dissolving it in chloroform and precipitating with ether, it was recrystallized from acetic ester without warming and found to melt at 119° to 120°. The quantity was small, but a reading made in an approximately 1 per cent acetic ester solution showed it to be decidedly lævo-rotatory.

Four or five days later an attempt was made to prepare more of the terpinolene tetrabromide from the purified oil. The tetrabromide obtained in acetic acid was recrystallized from acetic ester and now melted at about 120°. It appeared more like dipentene tetrabromide that it did like the derivative of terpinolene and on recrystallization melted at 125°. The expirement was carefully repeated twice; the bromide, dissolved in an equal volume of glacial acetic acid and well cooled was carefully added to an equally well cooled solution of the oil in 1.5 volumes of glacial acetic acid. The crude bromide, when recrystallized from acetic ester, melted from 118° to 120° with darkening, but in appearance and solubility it resembled dipentene tetrabromide. On recrystallizing again, it melted at 123° to 124°. This purified bromide was unquestionably that of dipentene, although the crude product appears to have been a mixture, for after the first recrystallization it was still impure.

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[14] *Ber. d. chem. Ges.* (1894), **27**, 447.

At this point it was found that the purified oil gave a decided test for phellandrene. The rotation of the oil was also found to have changed from +1°.7 to —1°.6. *After standing for five or six days longer, the oil gave a rotation of —9°.8 and one month after this of —34°.5, thus demonstrating that a rapid change was taking place spontaneously.* Three weeks later, the oil, which had stood in a cork-stoppered, partly filled flask, was distilled with steam. A small proportion of viscous, non-volatile matter remained, probably the result of oxidation of the oil upon standing. The distillate was separated from water and without further drying gave $\alpha^{30}_{D} = -38°$. To judge from this value, in comparison with that obtained three weeks previously, it was evident that the change taking place had about reached completion. In amyl alcohol and ether the oil now yielded a very good quantity of a crystalline bromide which was filtered off, washed and recrystallized from a mixture of acetic ester and alcohol. Melting point, 122° to 124°. 0.24 gram of the substance dissolved in about 8 cubic centimeters of acetic ester and placed in a 10-centimeter tube showed no appreciable rotation, so that the product apparently contained very little if any limonene tetrabromide. Certainly, the rotation of the oil can not be accounted for by the presence of lævo-limonene. A good quantity of the bromide was also obtained in acetic acid. After crystallizing once from a mixture of acetic ester and alcohol, it melted at 120° to 123°; on recrystallizing from acetic ester the melting point was 125°. The product melting at 120° to 123° remained perfectly colorless on fusion, thus differing markedly from that obtained from the oil after four or five days' standing. An attempt was now made again to prepare phellandrene nitrite from the oil and to determine its rotation. Although the presence of phellandrene in the oil was readily shown, it was now found impossible to isolate the nitrite in the presence of so much dipentene, the final product being a small amount of viscous matter adhering to the sides of the flask. This result is, of course, quite different from that obtained two months previously.

There appears to be no doubt but that the oil when first isolated was nearly pure terpinolene; that this terpinolene changed completely on standing into dipentene, a small amount of dextro-phellandrene and an unknown lævo-rotatory terpene. The boiling point of this terpinolene is considerably lower than that obtained by Baeyer for the product formed on reducing the tetrabromide. The present case is the only one in which the presence of terpinolene has ever been noted in a natural product.

LIMONENE.

Limonene is one of the most widely distributed terpenes. It occurs generally in the dextro-rotatory form, as the chief component of a number of the most important essential oils of commerce. From some of these it has been obtained in a fair degree of purity by fractional distillation, but the physical properties of the substance as given in the literature vary somewhat, depending upon the degree of purity with which it is possible to isolate it from the other constituents of those oils by the process mentioned. From caraway oil Schimmel and Co.[15] have isolated dextro-limonene which showed a rotation of $[\alpha]_D = +123°.6$ while Kremers[16] obtained $[\alpha]^{20}_D = +120°.46$ for the carefully fractionated portion of commercial carvene boiling at 174°.5 to 175°, and presumably from the same source. For the lævo-limonene of pine-needle oil, Wallach found $[\alpha]_D = -106°$. Godlewsky and Robhanowitsch[17] for the purpose of obtaining accurate data as to its physical constants, have succeeded in preparing what appears to be almost, if not quite pure, limonene by reduction of the pure tetrabromide. Their product which is described as constant-boiling, showed:—sp. gr. $\binom{20}{4} = 0.8425$; $[\alpha]^{20}_D = +125°.6$; boiling point, 177°.5 at 759 millimeters. Considering the small variation which I have found in the optical activity of the many constant-boiling samples of dextro-limonene obtained from different samples of *elemi*, this property appears to serve well as a check upon the purity of the limonene.

The following table of physical constants for dextro-limonene is taken from some of the samples which have a rotation close to the average:

Designation of product.	Boiling point complete.	α^{30}_D +	n^{30}_D	Sp. gr. $\binom{30}{4}$	Boiling point at reduced pressure.
	° °	°			
VIII,A, purified	176 -176.7	100.8	1.4679	0.8353	95°.3-96°.5, 60.5 millimeters.
XII,A, purified	176 -176.7	100.3	1.4682	.8350	
XIII,A, purified	176.5-177.5	100.1	1.4683	.8364	
IX,A, purified	176.5-177.5	100.3	1.4680	[18] .8371	
VI,A, purified	176 -176.7	99.9	---------	---------	93°-94°, 55 millimeters.
II,A, purified	176 -177	100.0	---------	---------	82°.5-83°.5, 36.5 millimeters.

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[15] Gildemeister und Hoffman, Die Aertherischen Oele (1899), 172.

[16] *Am. Chem. Jour.* (1895), **17**, 694.

[17] *Chem. Centrbl.* (1899), **70**, I, 1241.

[18] The high number probably has its cause in the age of the resin; the product was notably more difficult to purify than any of the others. Unfortunately, several of the samples of pure limonene were used up before their physical constants had been accurately determined.

Product, VIII, A, purified, showed: $n_{\mathrm{D}}^{25}=1.4705$ and $n_{\mathrm{D}}^{20}=1.4728$. An average difference of 0.0071 was found between specific gravity $\left(\frac{30}{4}\right)$ and specific gravity $\left(\frac{20}{4}\right)$ for three samples. The molecular refraction of limonene at 20° may therefore be calculated.

The value of the rotation given corresponds very closely to that noted by Kremers.[19] The latter states that the rotatory power of limonene changes considerably on standing, giving as an instance a sample the rotation of which had changed from +121°.3 to +103°.23. He also notes a corresponding increase in the specific gravity. I have found that a sample of pure limonene, sealed up in a nearly filled flask, suffered no noticeable change after standing four months, but several samples of pure limonene which were kept in glass-stoppered bottles were found to decrease gradually in rotatory power; the same is true of phellandrene. This change is undoubtedly caused by oxidation of the terpene. One sample of limonene which originally had a rotation of +100°.6 stood for about a year in a partly filled, glass-stoppered bottle. It was then redistilled with steam. A considerable amount of non-volatile matter remained behind and the distillate had taken on a "menthol" odor. The oil was redistilled *in vacuo* and then showed a rotation of +100°.2. It boiled completely from 176°.5 to 177°.5.

The behavior of limonene at elevated temperatures was also studied, the question being considered of considerable importance because of the readiness with which so many of the substances of the composition $C_{10}H_{16}$ change into isomeric bodies. Wallach[20] states that hesperidene (dextro-limonene obtained from oil of orange) is changed into dipentene by "*mehrstündiges*" heating at 250° to 270° and a similar statement, probably derived from this source, appears in many of the books dealing with this subject.

(1) Twenty-five grams of pure limonene ($\alpha_{\mathrm{D}}=100°.7$) were heated in a sealed tube at 275° to 290° for five hours. The product was then distilled with steam and a small amount of non-volatile matter, about 5 per cent of the original, remained behind. The polymerized product is only slightly soluble in alcohol. The distillate after having been dried over solid potassium hydroxide, showed exactly the same boiling point as the original. Its rotation was +99°.8 and its refractive index was practically unchanged. A tetrabromide was prepared in acetic acid and after recrystallizing once from acetic ester melted at 104°–105°, this being the melting point of pure limonene-tetrabromide.

(2) The limonene obtained from the last experiment was heated, together with 2 or 3 drops of water, in a sealed tube at 290° for ten hours, the temperature rising to 360° for a short time. On examining the contents of the tube the water still appeared and the product was colorless. After distilling with steam,

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[19] *Loc. cit.*

[20] *Ann. Chem.* (*Liebig*) (1885), **227**, 289.

about 10 per cent was found to have polymerized. The distillate when dried showed the same boiling point as before. The rotation had decreased a little: $\alpha_{D}^{30} = +97^\circ$.

(3) Twenty grams of pure limonene, together with 2 drops of water, were heated in a sealed tube at 200° for ten hours. The amount of polymerization was small. The boiling point was unchanged as well as the refractive index, although the rotation had decreased 0°.5.

(4) Twenty grams of pure limonene together with 1 gram of benzoic acid were heated in a sealed tube at 250° for seven hours. The product was extracted with a small amount of potassium hydroxide solution and all of the benzoic acid recovered, it was distilled with steam, only a small amount of residue remaining. After drying, the oil was redistilled and the boiling point found to be practically unaltered, although the rotation had decreased from +110°.1 to +98°.

(5) Twenty grams of practically pure limonene together with 1 gram of acetone were heated at 300° for six hours. The product was colorless. There was considerable polymerization. The boiling point of the oil was unchanged but the rotation has decreased from +98° to +96°.5.

(6) About 20 grams of pure limonene with 2 grams aniline were heated at 280° for seven hours. The product was extracted with very cold, dilute hydrochloric acid and distilled with steam. It then boiled completely from 176° to 177°. The rotation had decreased from +100°.2 to +99°.4.

(7) A few grams more of the pure substance were added to the limonene obtained from the last experiment and it was heated at 380° for six hours. The product was colorless. Approximately 15 per cent of the total had been polymerized. The boiling point of the distillate was unchanged, although the rotation had decreased to +93°.

It will be seen from the above experiments that if dipentene is formed from dextro-limonene at elevated temperatures, the change is an extremely slow one. Even at 380° it would take many hours for the formation of a sufficient amount of dipentene to allow of detection. Moreover, it does not follow that a decrease in the rotation implies the formation of dipentene, although from the unchanged boiling point, this seems probable. It will also be noted that the degree of polymerization is more than double that of inversion. From these experiments limonene is seen to be a very stable substance and almost indifferent to the influence of foreign reagents even with respect to its optical activity. It may repeatedly be distilled at ordinary pressure without any fear of its suffering alteration. It was found that after heating for eight hours in a tightly stoppered distilling bulb, placed in an oil-bath which was kept at a temperature of 180° to 220°, the distillate was identical in all respects with the original except that its rotation had decreased by about 0°.2.

The behavior of dilute mineral acids toward limonene does not appear to have been studied. Limonene is almost completely polymerized by the action of dilute sulphuric acid in glacial acetic acid; the same reagent in absolute alcohol converts it into optically inactive terpenes which have a considerably higher boiling point. Sulphuric acid in dilute alcohol, hydrates a large percentage of limonene.

(1) Twenty grams pure dextro-limonene were dissolved in 50 cubic centimeters of acetic acid of 99.5 per cent strength, and to this was added 1 gram of dilute sulphuric acid ($H_2SO_4,3H_2O$). This mixture was heated in a flask on a water-bath for seven hours, the flask having been connected with a calcium chloride tube in such a way as to prevent the access of moisture. Soon after the heating began, two layers formed. The product was finally thrown into water and the oil removed with ether, after which it was washed with sodium carbonate to remove acetic acid and then distilled with steam. The entire amount of distillate obtained was not over 2 grams; the residue was tarry. The limonene had been almost completely polymerized.

(2) Thirty grams of pure limonene were dissolved in 20 grams absolute alcohol and 1 cubic centimeter of dilute sulphuric acid ($H_2SO_4,3H_2O$) added. Access of moisture was prevented by means of a calcium chloride tube and the flask containing the mixture was heated just to boiling on a water-bath for fifteen hours, during which time the mixture became reddish brown in color. The product was finally poured into cold water and the oil separated. The latter was again shaken out with cold water and then driven over with steam. There had not been much polymerization. The distillate was dried over solid potassium hydroxide and then distilled. Two fractions of equal amount were obtained, (1) from 184° to 193°, and (2) from 193° to 200°; both showed only a slight rotation. Neither one gave a crystalline hydrochloride in acetic acid or a tetrabromide in amyl alcohol and ether. The first fraction gave no test for phellandrene but a very small amount of terpinene nitrite which had a melting point of 153°–154° appeared on standing. The first fraction showed $n\frac{30}{D}=1.4726$ and the second $n\frac{30}{D}=1.4690$. Since there could have been very little hydration, the product is composed mostly of unknown terpenes.

(3) Forty grams of pure dextro-limonene were dissolved in 350 cubic centimeters of absolute alcohol and to this was added 35 cubic centimeters of a mixture of 1 volume concentrated sulphuric acid and 5 volumes water. This mixture was boiled in a flask with a reflux condenser for seven hours on a water-bath. The alcohol was then partly distilled off and the residue driven over directly with steam. There was only a small amount of non-volatile residue. The distillate was separated from water and fractioned twice. The first time it boiled from 186° to 218° and on the second fractionation the following portions were separated. (1) 180° to 186°, 30 per cent of the total; (2) 186° to 193°, 25 per cent; (3) 193° to 200°, 15 per cent; and (4) 200° to 215°, 30 per cent. During the distillation a small amount of water appeared continuously to be formed. In the first fraction no phellandrene could be detected, but a small quantity of crystals, probably terpinene nitrite, formed on standing. They were contaminated with resinous matter and an accurate determination of their melting point, which was not far below 155°, was impossible. The same fraction gave a good quantity of crystalline tetrabromide in acetic acid. After recrystallizing twice, this product melted from 112° to 115° and is therefore probably a mixture of limonene and dipentene tetrabromides. The higher-boiling fractions were not very carefully investigated. An unsuccessful attempt was made to prepare a phthalic acid-ester by the action of phthalic anhydride upon fraction (4) in benzol solution. The products obtained in this experiment should be further studied.

Limonene hydrochloride.—This substance obtained by Wallach and Kremers[21] by the action of dry hydrochloric acid upon limonene, was prepared in order to study the action of aniline upon it. The substance was found to boil from 89° to 91° at 12 millimeters, and accordingly several degrees lower than the boiling point given by the above authors.

Thirty-four grams of the fractioned substance were added to an equal weight of aniline and the mixture heated on a water-bath. The temperature of the mixture gradually rose to 113° and in time aniline hydrochloride appeared. Previous experience had shown that above 120° the heat of the reaction was so great that, without careful cooling, the reaction mixture became very hot. The heating was continued for six hours upon the water-bath. The reaction-product was freed from aniline by repeatedly shaking with cold, dilute hydrochloric acid. The oil was then driven over with steam and redistilled twice. On the second distillation it boiled almost completely from 177° to 178°.5 and showed $\alpha^{30}_{D} = +55^\circ$. No crystalline nitrite could be obtained. A good yield of crystalline tetrabromide was produced in acetic acid, and this tetrabromide after being recrystallized twice from acetic ester, gave the melting point of dipentene tetrabromide. On heating the oil in a well-stoppered flask immersed in an oil-bath kept at 200° for four hours, there was practically no change in the rotation.

It appears that by the addition of hydrochloric acid to limonene and its subsequent splitting off, the limonene is partly converted into dipentene, but that no other substances are formed.

PHELLANDRENE.

A number of essential oils when treated with nitrous acid are known to separate at once a white, crystalline derivative, $C_{10}H_{16}N_2O_3$, to which the term phellandrene nitrite has been indiscriminately applied, although the melting point of the substance as recorded by various authors has varied within a large range. Schreiner[22] recently separated the product obtained from eucalyptus oil into two distinct substances by fractional crystallization from acetic ester. Since that time Wallach[23] has gone into this question most thoroughly. He has shown that the products obtained from bitter-fennel oil and *elemi* oil as well as from eucalyptus oil (the last named being dextro-rotatory, while the other two are lævo-rotatory) are homogeneous chemically, and that the two substances obtained from each of these oils are isomers only in a physical sense. The mother substance to which all of these products are to be referred he terms α-phellandrene. The less soluble nitrite he terms the α-nitrite. He has also shown that the nitrite obtained from water-fennel oil is chemically different from the others mentioned and to its mother terpene he has given the name β-phellandrene. With the identity of these different nitrites established, Wallach succeeded, by working with them, in determining the chemical constitution of the two phellandrenes.

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[21] *Ann. Chem.* (*Liebig*) (1892), **270,** 189.

[22] *Chem. Centrbl.* (1901), **72,** II, 544.

[23] *Ann. Chem.* (*Liebig*) (1902), **324,** 269; (1904), **336,** 9; (1905), **340,** 1.

So far as the terpenes themselves are concerned, there are very little data, chemical or physical, which may be looked upon as reliable. The physical properties recorded vary somewhat, but with the exception of the rotation do not differ greatly from those which I have found for pure phellandrene. Although phellandrene may be the predominant terpene in many of the fractioned products described in the literature, it must be remembered that most of the terpenes of this series are very closely related in physical properties and it appears to be very often true that only those of a certain class are to be found in the oil obtained from any one species. The optical rotation (α_D) of well-fractioned phellandrene products is seldom given as being higher than ±60°. Although phellandrene appears to be converted completely into the nitrite, it was found almost impossible to dry the filtered and well-washed product so as to weight it accurately. This difficulty is caused by the tendency of the crude substance to become slightly resinous. In solvents it undergoes rapid decomposition.

In nearly all of the terpene oils obtained in this work, which were found to contain phellandrene, the latter was examined and found to be α-phellandrene determined by isolating the α-nitrite described by both Schreiner and Wallach. The method usually employed was to dissolve the crude product, dried as well as possible by presure between filter paper, in a very small amount of chloroform, then filtering to remove water and precipitating the nitrite with ether; it was afterwards recrystallized once or twice from acetic ester. Wallach gives 112° to 113° as the melting point of the substance while Schreiner found 120° to 121°. During the first work which I did with this substance it was recrystallized from hot solvents and the melting point seemed to depend somewhat upon the solvents used. When acetic ester was employed the final melting point was always 113° to 115°. It was finally found that by dissolving the nitrite in acetic ester at 30° and then crystallizing in a freezing mixture, the melting point given by Schreiner was obtained. When the pure α-nitrite was again recrystallized from hot acetic ester, its melting point was lowered to about that found by Wallach. The latter used hot acetone in purifying his product and the low melting point does not indicate that the substance with which he worked was impure. The conclusions drawn by Wallach from his work with this substance are based upon the assumption that it was free from chemical or physical isomers.

Rotation of the nitrite.—The optical rotation found by Wallach for the α-nitrite obtained from two different sources was considerably higher than that found by Schreiner. In fact the numbers given by Wallach for the same product show a considerable variation. Both workers used chloroform as a solvent. By the use of the same solvent I obtained a value agreeing very closely with that of Schreiner, the solution having stood for about ten minutes before the reading was made. It was found later that the reading diminished quite rapidly on standing.

(1) A solution of 0.35 gram of pure α-phellandrene α-nitrite dissolved in 5 cubic centimeters of pure chloroform (Kahlbaum, best quality, shaken out repeatedly with water, dried over calcium chloride and then distilled) lost its optical activity entirely after standing for about four hours. The solvent was evaporated *in vacuo*. The residue did not crystallize until a small amount of ether was added, which evidently dissolved out some amorphous decomposition products. The recovered product which was fully three-fourths of the amount used originally, was again dissolved in 5 cubic centimeters of fresh chloroform and the solution was found to be slightly lævo-rotatory, the value being about one-tenth that of the original.

(2) A solution of 0.3 gram pure α-nitrite in 10 cubic centimeters of chloroform after standing for eighteen hours showed a positive rotation equal to about one-half that of the original negative value.

(3) A solution of 0.5 gram pure α-nitrite in three or four cubic centimeters of chloroform was allowed to stand over night. The chloroform was then for the greater part removed *in vacuo* and the residue treated with a small amount of ether. The solid residue was pressed out on a porous plate and again washed with ether. It consisted of a little more than 0.3 gram. When recrystallized from acetic ester it melted at 120° to 121° and the rotation of the recrystallized substance, roughly determined in dilute chloroform solution, was found to be about the same as that of the original pure α-nitrite.

(4) A saturated solution of the pure nitrite in acetic ester showed $\alpha_D = -6°.2$. A reading made some time later demonstrated that the rotation of the solution was decreasing. After standing over night it had changed to $+1°.8$. The solvent was then removed *in vacuo* and the residue washed well with ether, only about one-fourth of the weight of original nitrite remaining. When this was recrystallized from acetic ester it melted at 119°.5 to 120°.5 and showed a rotation approximately the same as the original.

From above experiments it seems certain that the change in rotation is not caused by a change of the dextro-into the lævo-α-nitrite, although otherwise the results obtained do not appear at all clear.

Wallach has shown that there is no change in melting point when the dextro-and lævo-α-nitrite are mixed; hence the racemic mixture appears to be very similar to the active forms. It was desired to determine whether the varying rotation found for different samples of phellandrene could be explained by the presence of the racemic modification and it was thought that this could be determined from the rotation of the purified nitrite. In the case of the nitrite from oil XVII,A, purified, the value $[\alpha]_D^{30} = -126°.8$ at a concentration of 12.3 was found. The nitrite obtained from XIV, A, purified, gave $[\alpha]_D^{30} = -124°.5$ at a concentration of 8.84. Both readings were taken about ten minutes after the solutions were made and from the rate at which the rotation was found to decrease, the immediate values would be about those found by Wallach. From this there appears no evidence that any racemic form of phellandrene is present in either of the two oils, the first of which had a value, $\alpha_{D}^{30} = +73^\circ.5$ and the second, $_{D}^{30} = +105^\circ$. Later, another cause was discovered for this varying rotation of the phellandrene oils.

Stability of phellandrene.—Wallach[24] recognized the fact that phellandrene is not a stable substance and recommended that it be fractioned *in vacuo*. Nothing further is to be found in the literature upon the subject. It was ascertained that a sample of phellandrene after distillation at ordinary pressure had a rotation which was about 2° lower than it had been before this process.

(1) The distilled product just mentioned was heated in a tightly stoppered distilling flask, immersed in an oil bath, and maintained at 190° for eight hours, after which time it was distilled from the flask; about one-fifth of the total remained as a viscous residue almost insoluble in alcohol. The oil redistilled from 172° to 174° which is a temperature a little higher than the boiling point of the original. Its rotation had decreased from +105° to +70°.

(2) The last distillate obtained was then sealed in a hard-glass tube and heated in an oven for twenty-four hours at 250°. The product was colored a slight yellow. It was distilled with steam, whereupon about 15 per cent of non-volatile matter remained behind. The distillate showed $\alpha_{D}^{30} = -25^\circ.5$. It boiled completely from 171° to 176.°5. Phellandrene was no longer present and after careful trials no other terpenes could be identified. The oil had a very peculiar, benzene-like odor which was quite different from that of any other terpene.

(3) The experiment was repeated with a fresh amount of the original sample of phellandrene. This time the heating was carried on at 225° for twenty-four hours. The product was colored slightly yellow. It was distilled with steam and a residue of nearly 25 per cent remained behind. The distillate had the same peculiar, benzene-like odor and gave a very slight test for phellandrene; $\alpha_{D}^{30} = -23.8$. It boiled completely from 171°.5 to 176°.5. It appeared to be identical with the product obtained in the last experiment.

(4) The combined residues obtained in this and the preceding experiments were distilled at 10 or 15 millimeters. A proper thermometer was not used so that the result of the distillation could only be roughly judged. A small amount of terpene oil passed over first, then a quantity of higher boiling, somewhat viscous oil distilled before the temperature had risen much beyond 200°. Later, decomposition set in, the temperature went much higher and the distillate was very viscous. It appeared certain, however, that one of the polymeric products of phellandrene, probably a diterpene, may be distilled without decomposition.

In order to obtain evidence as to whether or not phellandrene is converted into the racemic form by heating, a quantity of very pure phellandrene (XVI,A, purified) was heated in a sealed tube at 200° for ten hours.

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[24] *Ann. Chem.* (*Liebig*) (1895), **287,** 372.

The product was distilled with steam and the distilled oil showed $\alpha\ {}^{30}_{\mathrm{D}} = +38°$. Phellandrene nitrite prepared from this in the usual manner melted at 119° to 120°.5 after the first recrystallization from acetic ester. In chloroform solution at a concentration of 3, the specific rotatory power was found to be about the same as that produced in previous cases by the α-nitrite and therefore there was no evidence that any racemic phellandrene had been formed.

After what has been brought out concerning the rapid change in rotation which the nitrite undergoes in solution, it must be borne in mind that the values obtained for this property of the nitrite are only approximate, but when they are taken for different samples under the same conditions, they are abundantly adequate for purposes of comparison.

The phellandrene used in the heating experiments (1), (2), and (3) was taken from sample XIV,A, purified, which, as will be brought out later, contained a small amount of lævo-limonene. The process was therefore repeated with a quantity of XVI,A, purified, which, so far as it was possible to determine, is pure phellandrene. The substance was heated in a sealed tube for forty-eight hours at 210° to 215°. The product was colorless. The oil after having been distilled with steam still gave a slight test for phellandrene and showed $\alpha\ {}^{30}_{\mathrm{D}} = -18°$. The lævo-rotation of the product appears therefore to be due to a product of isomerization of phellandrene. This oil, when dissolved in cold carbon tetrachloride and heated with bromine, combined at once with less than 2 atoms of the latter and considerable hydrobromic acid was evolved. Further action was much slower. The same result was obtained in glacial acetic acid, although in this case the evolution of hydrobromic acid was not so apparent, as it was probably held in solution by the acetic acid.

A portion of the same sample of freshly purified phellandrene used in the last experiment was sealed in a nearly filled flask and allowed to stand for three months. The original rotation was $\alpha\ {}^{30}_{\mathrm{D}} = +129°.8$. On opening the flask it was found to be $\alpha\ {}^{27.5}_{\mathrm{D}} = 127°.1$, accordingly a decrease of about 3°. Phellandrene, therefore, undergoes a slow alteration at ordinary temperatures, probably the same which takes place more rapidly at a higher temperature.

Action of hydrochloric acid.—About 30 grams of phellandrene, taken from the oil, V,A, purified, were heated with metallic sodium for a few minutes, then distilled from the later into a dry fractioning flask ($\alpha\ {}^{30}_{\mathrm{D}} = +115.5°$) and mixed with an equal volume of dry carbon disulphide. A slow stream of very dry hydrochloric acid was then passed into the liquid, the exit tube having been attached to a tube of calcium chloride. The acid was readily absorbed and the liquid appeared to become heated more quickly than when limonene had been employed under the same conditions. It was kept cool by immersing the flask in a dish of water. After four or five hours, the absorption appeared to be nearly complete, but the current of acid was continued for several hours longer. The contents of the flask were then distilled at reduced pressure. After the excess of acid and the carbon disulphide had been removed, the residue was distilled at as low a presure as could be maintained, considering that hydrochloric acid appeared continually to be given off. The product boiled completely within a range of 15° or 20°; the distillate contained much terpene and possessed a very strong odor of hydrochloric acid. Phellandrene behaves quite differently from limonene, and the hydrochloride which appears to be formed at ordinary temperature is decomposed to a large extent by distillation at reduced pressure.

Action of bromine.—Several investigators have studied the action of bromine upon phellandrene-containing oils and from their work it appears that the substance takes up at once only 2 atoms of bromine to form an oily dibromide. It was desired to ascertain whether this dibromide, when produced from pure phellandrene, could be obtained in the crystalline form.

Three and one-tenth grams of phellandrene, taken from sample XVI,A, purified, were dissolved in 3 volumes of carbon tetrachloride and the solution cooled in a freezing mixture; 3.4 grams bromine (2 atoms) dissolved in 3 volumes of the same solvent and cooled were then slowly added to the first solution, which was continuously shaken, while immersed in the freezing-mixture. The color of the bromine disappeared immediately, until nearly all had been added; the last few drops producing a color which remained for over one minute and fumes of hydrobromic acid then appeared. The solution was then evaporated *in vacuo* for several hours in order completely to remove the solvent. The residue, a quite mobile oil, was allowed to remain in the ice chest for twenty-four hours, but did not crystallize.

Crystalline auto-oxidation product of phellandrene.—It was frequently observed that samples of purified oils on standing deposited a greater or less quantity of crystals upon the walls of the containing vessel. In most cases, even after long standing, the amount of crystalline substance was small in proportion to that of the oil but in several instances about 0.2 gram was obtained from 50 to 75 grams of oil. One sample of purified, high-boiling oil, not over 25 grams in amount, deposited nearly 0.5 gram of this crystalline substance soon after distillation. It was later observed that in no case were crystals found in an oil derived from a sample of *elemi* known not to contain phellandrene. Although at this time some of the oils had been completely used up, it was observed that more or less of the crystalline substance could be found in both the terpene and the high-boiling oils on hand, which were derived from phellandrene-containing samples. It seems almost certain that the substance is derived from phellandrene. In all cases which were studied, the crystals from different oils were found to be identical. They are moderately soluble in alcohol and acetic ester, sparingly so in ether and chloroform and almost insoluble in petroleum ether. They are best purified by recrystallization from hot acetic ester, from which solvent they separate on cooling as fine needles, melting at 164°.5 to 165°.5. In most cases they were pure after the first crystallization. In the condition in which they are encountered in the oil, the crystals are colorless, hexagonal prisms generally of good size; two of the largest weighed, when taken together, just 1 centigram. The body is probably the same as that noted by Tschirch and Cremer and also previously observed by Wallach in *elemi*-oil. Analyses gave the following results:

(1) 0.1667 gram substance gave 0.4322 gram CO_2 and 0.1607 gram H_2O.

(2) 0.0713 gram substance gave 0.1853 gram CO_2 and 0.0708 gram H_2O.

Required for $C_{10}H_{18}O_2$	Found	
	(1)	(2)
Per cent	Per cent	Per cent
C=70.59	70.71	70.87
H=10.59	10.71	11.03

The substance is probably a dihydroxy-phellandrene. That it is of the simple formula given, rather than a polymer, is indicated by the fact that it sublimes very readily when it is heated below its melting point.

As to the physical constants of phellandrene, the values obtained from XVI,A, purified, should be given preference. Those of several of the other samples, most of which it will be seen later contain small amounts of lævo-limonene, are also given in the following table there being of course very little difference except in the degree of rotation.

Designation of product.	Boiling point complete.	$\alpha\, {}^{30}_{D}$ +	$n\, {}^{30}_{D}$	Sp. gr., $\left(\frac{30}{4}\right)$	Boiling point at reduced pressure.
	° °	°			
XVI,A, purified	172–173.5	129.8	1.4695	0.8324	89°.3 to 90°.8, 56.5 millimeters.
V,A, purified	172–174	122.6	1.4698	----------	82°.7 to 84°, 43.5 millimeters.
XIV,A, purified	----------	105.1	1.4694	.8322	
XVIII,A, purified	172–173.5	113.5	1.4696	.8330	

Two determinations each gave the specific gravity at $\left(\frac{30}{4}\right)$ as being 0.0075 less than that at $\left(\frac{20}{4}\right)$.

The boiling point of phellandrene is seen to be about 4° lower than that of limonene; the specific gravity is a little less while the index of refraction is somewhat higher.

In discussing the constitution of phellandrene Wallach[25] has recently deduced the molecular-refraction of the substance, deriving his number from the phellandrene obtained from *elemi* oil by fractionation. From the present work it can be seen that this "phellandrene" was partly limonene, although it can also be seen that the limonene would have little influence upon the value obtained.

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[25] *Loc. cit.*

TERPINENE.

Terpinene has been identified in only two essential oils, and in these cases by means of its nitrite, which separates in the crystalline form on treating the oil dissolved in ligroïn with nitrous acid and allowing the reacting substances to stand. Both of these oils contained a mixture of terpenes and from these it is possible to learn very little concerning terpinene itself. The latter has also been shown to be present in a number of products resulting from chemical operations in the laboratory, but it appears always to be largely mixed with other terpenes. In general, fractions of terpinene-containing oils which boil at about 180° appear to have given the best yields of the nitrite.

The purified terpene oil obtained from *Sample IV* was practically inactive, it boiled almost completely from 174° to 175°.5 and every effort made to detect some other terpene in it was without success. It gave a good yield of terpinene nitrite, which appeared very soon after the addition of the nitrous acid.

There is every indication that the oil was pure terpinene, although the boiling point was lower than would be expected. The following experiments shown how poorly we are able to judge of the boiling point of terpinene, if we take as a criterion that of products containing it.

(1) A quantity of phellandrene ($\alpha_D = +122°$,) was added to an equal volume of alcoholic sulphuric acid consisting of 2 parts alcohol, 1 part water and 2 parts acid, by weight. The mixture was placed in a flask and heated upon the water bath, with a reflux consider, for six hours. It was then added to water, the oil taken up in ether and driven over with steam; it was then redistilled and divided into two fractions: (1) 175° to 177°; (2) 177° to 182°. Neither fraction gave the test for phellandrene. Both gave crystals of terpinene nitrite, but these appeared more quickly in (1) and were more abundant than in (2).

(2) A terpinene-containing oil was prepared according to Wallach[26] by the action of alcoholic sulphuric acid upon pinene. The oil was fractioned into four portions. The second fraction, 175° to 180°, gave no terpinene nitrite, while the third, 180° to 185°, gave a small amount.

Terpinene does not differ much in physical properties (see *Sample IV*), from limonene, except in refractive power.

The isolation of a considerable quantity of terpinene will afford an excellent opportunity for studying the constitution of this terpene. The purified oil which I had at my disposition was not great in amount and some of it was used in other work. The quantity remaining was not deemed sufficient to undertake the problem. Preliminary experiments showed that a considerable proportion of a crystalline acid was formed by oxidation with 4 per cent permanganate in the cold. The product obtained appeared to be a mixture.

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[26] *Ann. Chem.* (*Liebig*) (1885), **227**, 283.

CLASSIFICATION OF THE TERPENE OILS.

(1) Of the 21 samples examined, 10 gave pure dextro-limonene.

(2) Nine of the remaining oils, including all but the two optically inactive ones, contained more or less phellandrene. The nine phellandrene-containing oils fall into two classes.

(*a*) Those showing an initial boiling point decidedly lower than that of phellandrene and possessing a peculiar, indefinable odor. These are the oils from *Samples VII, X,* and *XV,* and all are dextro-rotatory. The oil from *Sample X* has the lowest initial boiling point and its rotation is decidedly the smallest. The data obtained upon the physical constants of these oils do not lead to any decided conclusion, but it appears extremely improbable that any body like pinene is present in them. From the marked regularities which are found to exist in the different samples, it seems very probable that we have present in these three cases one of the unidentified terpenes of the limonene series.

(*b*) Of the remaining six phellandrene-containing oils from *Samples V, XI, XIV, XVI, XVII,* and *XVIII,* one was lævo-rotatory and the others, although they were all highly dextro-rotatory, showed a considerable variation in rotation. The two giving the greatest variation also had a slightly higher boiling point, while the others, to judge from their boiling point, appeared to be pure phellandrene. As has already been brought out in the discussion of *Sample XI,* this oil consisted largely of lævo-limonene.

In summing up this work it was suspected that the variation in the rotation of the other phellandrene containing oils was due to the presence in them of small amounts of lævo-limonene which could not be detected. As shown in the experimental work which is detailed just below, the presence of lævo-limonene could readily be proved by the addition of a small portion of dextro-limonene to the oil and the subsequent isolation of dipentene tetrabromide. The presence of lævo-limonene was prove in oils XVII,A, purified, and XVIII,A, purified. XIV,A, purified, had been used up in previous work. In V,A, purified ($\alpha_D = +122°.6$) and XVI,A, purified ($\alpha_D = 129°.8$), it can not be definitely concluded whether or not lævo-limonene was present and it can be readily seen that if present at all it was in very small amounts.

Detection of lævo-limonene.—A portion of XVII,A, purified, was added to one-fifth its weight of dextro-limonene and 3 grams of the mixture treated in a freezing mixture with bromine in amyl alcohol and ether. Crystals began to separate very quickly and after two or three hours they were filtered and washed with a small amount of alcohol. Yield, 0.8 gram. When recrystallized from alcohol the melting point was 118° to 121°. The latter was not altered much by recrystallizing twice from a mixture of alcohol and acetic ester. The final melting point was 118° to 120°. The product was apparently a mixture of dipentene and limonene tetrabromides. A sample of pure dipentene tetrabromide was then mixed with about 10 per cent of pure dextro-limonene tetrabromide and the product, after being recrystallized once from a mixture of alcohol and acetic ester, melted at 117° to 119°. This confirmed the previous conclusion.

As too great a proportion of dextro-limonene appeared to have been added in the last experiment, it was repeated, using just about one-half the amount. From 0.45 gram of the mixture there was obtained, after three hours, 0.65 gram of dry crystals which, after having been recrystallized once from a mixture of alcohol and acetic ester, melted at 124° to 125° and the substance was accordingly dipentene tetrabromide.

Four grams of XVIII,A, purified, were mixed with 0.4 gram of dextro-limonene and treated with bromine as before. After the product had stood over night, 0.2 gram of crystalline bromide was obtained, this being only about one-third of the amount isolated in the previous case. After recrystallization from a mixture of alcohol and acetic ester the body melted at 124° to 125° and was accordingly pure dipentene tetrabromide.

Both V,A, purified, and XVI,A, purified, the former at least presumably containing a very small proportion of lævo-limonene, were treated with 15 per cent of their weight of dextro-limonene and brominated in the usual manner. In neither case had a trace of the crystalline product separated after twenty-four hours but in each instance after two or three days, a small quantity of crystals appeared which, after recrystallization, melted at about 124°. No great significance is attached to this for it was found that XVII,A, purified, when it was brominated without the addition of limonene after standing for several days yielded a very small amount of crystals which had about the same melting point; the appearance of dipentene tetrabromide in these cases is possibly due to the continued action of hydrobromic acid upon limonene tetrabromide.

(3) The two remaining samples of resin gave almost optically inactive oils which were found to be terpinene and terpinolene.

HIGH-BOILING OILS.

The data obtained from the purified, high-boiling oils are placed in the table below, in order to make plain the relations existing between them. The boiling points at reduced pressures have already been given under the different samples. These different boiling points were taken at somewhat different pressures, as it was not possible to obtain the same pressure from day to day. However, the variation in pressure was not great and it may be seen that the boiling points of the many different constant-boiling products isolated were almost the same, the differences not being over 2° or 3° when referred to a common pressure. These oils did not boil as constantly as the pure terpene oils which were isolated, but they passed over completely within a range of from 2°.5 to 3°.5.

Designation of oil.	Sp. gr., $\left(\frac{30}{4}\right)$	$\alpha\frac{30}{D}$	$n\frac{30}{D}$	Approximate solubility in 100 parts 55 per cent alcohol (by volume).
IV,C, purified	1.0315	° −1.2	1.5159	16
I,C, purified	1.0247	±0.0	1.5143	------------
XIII,B, purified	.9969	−0.5	1.5068	------------
III,B, purified	.9887	−2.5	1.5055	7.5
VII,C, purified	.9689	−2.5	1.5005	------------
VI,B, purified	.9621	[1]	1.4995	------------
VIII,B, purified	.9559	−2.4	1.4985	4
XVIII,B, purified	.9559	+2	1.4950	------------
II,C, purified	.9522	−2.7	1.4973	------------
XIV,B, purified	.9482	−2	1.4957	------------
XVI,B, purified	.9461	−0.8	1.4941	3
XII,B, purified	.8677	+71.6	1.4757	3

[1] Not determined.

In this table every measurement which has been made is recorded. In two or three cases, as already stated, it was found impossible to obtain a constant-boiling product from the crude distillate and in other instances no high-boiling distillate was taken.

The oils are arranged in the order of their specific gravities and it will at once be seen that the indices of refraction arrange themselves in precisely the same way, with the exception of XVIII,B, purified, which has an index about 0.0035 lower than it should have. This same oil is also exceptional in that it is slightly dextro-rotatory, while all the others are slightly lævo-rotatory. All the oils are practically optically inactive excepting XII,B, purified, which stands apart in all respects from the others.

Analyses of XII,B, purified, are as follows:

(1) 0.1455 gram substance gave 0.4309 gram CO_2 and 0.1503 gram H_2O.
(2) 0.1490 gram substance gave 0.4405 gram CO_2 and 0.1534 gram H_2O.

Required for $C_{15}H_{26}O$	Found	
	(1)	(2)
Per cent.	Per cent.	Per cent.
C=81.08	80.77	80.63
H=11.71	11.48	11.44

The analyses are in tolerably good agreement with the formula assigned. The substance, which had remained as an oil for three months after purification, become solid when the inside of the bottle was scratched with a glass pipette. It dissolved in all the organic solvents in any proportion and when an attempt was made to recrystallize it from dilute alcohol in the cold, it separated as an oil. The body is almost colorless and possesses a mild, pleasant odor. It is moderately viscous. At ordinary pressure it distills at 270° to 280° with the formation of water.

A half dozen or more oxygen-containing substances, mostly crystalline, have been isolated from the high-boiling portions of different essential oils. They have, in general, the same properties as this body and to most of them the same chemical formula has been assigned. They are sometimes known as sesquiterpene alcohols. To judge from the data given in the above table, the body is radically different from any of the other constant-boiling product isolated from different samples and as will be seen later, it is not a constituent of any of these oils. It is evidently practically a pure substance and its occurence in this single sample is most remarkable.

All of the other oils given in the table are closely related and are grouped together. In addition to the regular variations already noted, there is a constant increase in viscosity from the first oil to the last. The first, IV,C, purified, is very mobile, while the last, XVI,B, purified, is very viscous. All of these regularities at once suggest that we have in these different products a mixture of two substances in varying proportions and this is undoubtedly the case. The following analyses tend to confirm this view. The numbers obtained for XVI,B, purified, are:

(1) 0.1911 gram substance gave 0.5533 gram CO_2 and 0.1934 gram H_2O.
(2) 0.1630 gram substance gave 0.4721 gram CO_2 and 0.1637 gram H_2O.

Found

(1) Per cent.	(2) Per cent.
C=78.96	79.00
H=11.24	11.16

The analysis of XIV,B, purified, gave the following results:

(1) 0.1482 gram substance gave 0.4286 gram CO_2 and 0.1460 gram H_2O.
(2) 0.1580 gram substance gave 0.4547 gram CO_2 and 0.1589 gram H_2O.
(3) 0.2116 gram substance gave 0.6132 gram CO_2 and 0.2137 gram H_2O.

Found

(1) Per cent.	(2) Per cent.	(3) Per cent.
C=78.87	78.49	79.03
H=10.95	11.17	11.22

The figures obtained for III,B, purified are as follows:

(1) 0.1683 gram substance gave 0.4629 gram CO_2 and 0.1533 gram H_2O.
(2) 0.1714 gram substance gave 0.4709 gram CO_2 and 0.1500 gram H_2O.

Found

(1) Per cent.	(2) Per cent.
C=75.01	74.93
H=10.12	9.72

IV,C, purified, gave the following numbers:

(1) 0.1504 gram substance gave 0.3917 gram CO_2 and 0.1163 gram H_2O.
(2) 0.1887 gram substance gave 0.4917 gram CO_2 and 0.1420 gram H_2O.
(3) 0.2388 gram substance gave 0.6245 gram CO_2 and 0.1850 gram H_2O.

	Found		
	(1)	(2)	(3)
	Per cent.	Per cent.	Per cent.
C=	71.03	71.07	71.32
H=	8.59	8.36	8.79

Analysis (3) was made of a middle fraction of the substance, redistilled in a vacuum.

If we consider that these oils belong either to the terpene or sesquiterpene class, and are composed of the substances having the formula $C_{10}H_{16}$, $C_{15}H_{24}$ or their oxygen derivatives, then taking the boiling point into consideration we have in general three posibilities, namely, (1) a sesquiterpene or (2) a dioxygen derivative of a terpene or (3) a monooxygen derivatives of a sesquiterpene may be present. The sesquiterpenes are almost insoluble in dilute alcohol; the solubilities in 55 per cent alcohol (by volume) respectively of pure cadinene prepared from the hydrochloride and pure cedrene, distilled from oil of cedar, were determined and found to be practically *nil.* The different, high-boiling oils from *elemi* were then tested with the result that they showed a considerable solubility in 55 per cent alcohol; this solubility which in several instances is given in the table, varied just as do their other properties. In a few instances there was evidence of a trace of sesquiterpene, but the amount was inconsiderable. That the soluble constituents of the oil would have no great effect upon the solubility of a sesquiterpene, if such a substance were present, was shown by adding a small amount of the latter to several of the clear solutions.

The solubility of oil XVI,B, purified, the last one of the series, is very close to that of the pure sesquiterpene alcohol XII,B, purified (see p. 34), so that the assumption that we have here a substance similar to the latter seems to be verified. Moreover, the analysis of XVI,B, purified, shows that its composition is close to that of a sesquiterpene alcohol. On the other hand, the member at the other extreme of the series IV,C, purified, has a much greater solubility in 55 per cent alcohol, this property being remarkable. Considering the analysis and the boiling point, the latter substance is a dioxygen derivative of a terpene and is nearly pure; all of its properties are in accord with this assumption. The numbers obtained on analysis show too great a difference from any formula which can be calculated for the oil for it to be considered as being pure. $C_{10}H_{14}O_2$ requires 72.28 per cent for carbon and 8.44 per cent for hydrogen. This oil is slightly yellow in color, of a very mild, pleasant odor and is perfectly miscible with all the solvents. It redistilled from 275° to 279° at ordinary pressure, with the formation of water.

The other oils are all more or less yellow in color. Because of the great viscosity of the oils in the lower part of the series and also because of their lack of optical activity, it seems certain that the sesquiterpene derivative contained in them is quite different from the optically active substance XII,B, purified.

AMYRIN.

The crystalline residue obtained from *elemi* by treating it with alcohol has been worked with by many chemists and has long been known as amyrin. Banp,[27] who appears to have employed Manila-*elemi* in his work, gives 174° as the melting point of the substance. Vesterberg [28] who also used Manila-*elemi* was unable to obtain a constant melting point and showed that the substance is a mixture of two very similar bodies, which were separated by means of their acetyl derivatives; these bodies are α-amyrin, melting point 180° to 181°, and β-amyrin, melting point 193° to 194°. Tschirch and Cremer give 170° to 171° as the melting point of amyrin from Manila-*elemi,* after repeated crystallization.

I wished to note if there was any variation in the amyrin obtained from individual samples of *elemi;* it was thought that possibly α-amyrin or β-amyrin might be found in a pure condition, when derived from the resin of a single tree.

Two samples, VIII, from which had been isolated pure limonene, and XVIII, which had yielded almost pure phellandrene, were examined. In neither case could a body of constant and sharp melting point be obtained; the products resulting from several recrystallizations behaved as mixtures, although compartively, they melted at about the same temperature.

CHANGES IN THE RESIN ON STANDING.

Portions of three of the samples of resin used in this work were allowed to stand for about fifteen months in covered jars, at the end of which time they were still moderately soft.

(1) *Sample IV* yielded much less terpene oil when heated to 150° than it had formerly. The oil, after having been purified in the usual manner, distilled almost completely from 82° to 84° at 38.5 millimeters, this being the same as the boiling point of the pure oil isolated from this sample fifteen months before. Essentially it had undergone considerable change. Its physical constants are given in comparison with those of IV,A, purified, previously isolated. The oil obtained from the old resin when treated with nitrous acid, yielded only a very small

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[27] *Jahresb. f. Chem.* (1851), 528.

[28] *Ber d. chem.* Ges. (1887), **20**, 1243; (1890), **23**, 3187.

amount of terpinene nitrite, whereas the oil IV,A, purified, which had stood in a bottle for fifteen months still gave a very rich yield of the nitrite.

	$\alpha\frac{30}{D}$	$n\frac{30}{D}$	Sp. gr., $\left(\frac{30}{4}\right)$
IV,A, purified	° +4.3	1.4756	0.8358
Oil obtained after standing	+ .6	1.4800	.8425

(2) *Sample V* was distilled by heating it to 135°. The terpene oil was purified in the usual manner and boiled completely within about 2°. It was found still to be largely phellandrene although it differed somewhat from V,A, purified, which had been previously isolated from this sample. The refractive index had increased by about 0.0030 and the rotation had fallen from +122°.6 to +81°.2.

(3) *Sample VI* was heated to 150° and the terpene oil removed. The purified product was found to be dextro-limonene, practically unchanged, $n\frac{30}{D}=1.4679$. $\alpha\frac{30}{D}=+100°.3$.

According to these results limonene is unchanged by reason of the continued standing of the resin containing it, whereas phellandrene and terpinene are both largely altered. For reasons already given it was impossible to remove and purify the high-boiling oils of these samples.

DESTRUCTIVE DISTILLATION OF THE RESIN.

When *elemi* is distilled at ordinary pressure, nearly all of the terpene oil, accompanied by the free water in the resin, first passes over with practically no decomposition in the latter. By increasing the heat, a large amount of the high-boiling oil may be driven off, but at the same time the resin undergoes some decomposition. Finally, by continuing the heating, the residue may be decomposed and largely converted into volatile products, including water, gases, low-and high-boiling oils; the final residue is a very viscous, black tar, constituting about 15 per cent of the original resin. The total amount of products which may be condensed, including 5 or 10 per cent of water, is nearly 70 per cent of the weight of the resin.

A total distillate of 300 grams of oil obtained in one experiment was redistilled and gave the following fractions: (1) To 250°, 155 grams; (2) 250° to 300°, 75 grams; (3) 300° to 360°, 45 gram. The residue was very viscous and dark colored.

In another experiment the original distillate was separated into 3 fractions: (1) Twelve per cent of the resin, that portion taken until a thermometer placed in the neck of the flask had reached 210°; (2) 15 per cent of the resin, from 210° to 270°; (3) 37 per cent of resin, that part formed by a slow, destructive distillation of the residue; in this case the temperature recorded by the thermometer depended very largely upon the rapidity of the distillation. The different fractions were redistilled with the following results:

(1) 170° to 180° almost completely; residue added to (2); 25 per cent to 200°.

(2) 30 per cent from 200° to 260°; 40 per cent from 260° to 280°; residue added to (3).

(3) 10 per cent below 200° beginning very low; 30 per cent from 200° to 250°; 30 per cent from 250° to 300°; 15 per cent from 300° to 350°.

The separations made in the above experiments are naturally incomplete, but they give an approximate idea of the composition of the crude distillate. It will be seen that a product boiling below 300° constitutes over one-half the weight of the original resin, which product may be separated into about equal parts of low-boiling and high-boiling oils, the point of separation being between 200° and 225°. A smaller portion of a more viscous oil, having about the consistency of rosin oil, is also obtained. The low-boiling oil resulting from the decomposition contains a small proportion of very volatile constituents. All of the oils obtained in these experiments were colored and, except the terpene oil removed before decomposition of the resin had begun, possessed on offensive odor. The colored products when redistilled are almost colorless, but change again on standing.

ELEMI OIL IN THE AGGREGATE.

The combined results obtained by a careful examination of the oils obtained from 21 individual samples of resin establish the true composition of *elemi* oil so far as these samples may be considered as representative of the aggregate product. In several cases, notably in the last sample examined, substances were obtained which were not encountered in any other; it seems possible, therefore, that were the investigation continued, still others would be found in which new constituents would appear, although such cases would be rare and the substances themselves would constitute so small a proportion of the aggregate oil that they would scarcely need to be taken into account.

It is obvious that in considering Manila-*elemi* or the oil obtained therefrom as products of a species, we must deal with an aggregate sample of these products; a sample derived from so great a number of individual trees that the peculiarities of the individuals disappear. If the native gatherer of resin untilizes a large number of trees and regularly removes the resin from them in small portions, the product which he places upon the market will be nearly homogeneous and a representative sample; but if he obtains his resin from a limited number of individuals his product will not be representative and, if he utilizes resin which has accumulated upon the trees in large quantity, it will not be homogeneous.

The great variation which I found at different times in the oil obtained from commercial *elemi* is readily explained. It is plain what the composition of *elemi* oil is when considered as an aggregate product; it should be remembered that to the lævo-limonene which accompanies phellandrene should be added an equal amount of dextro-limonene and the whole considered as dipentene.

Granted that we have a representative sample of resin, the composition of the oil will also be influenced by the following factors:

(1) The age of the resin.

(2) The temperature of the distillation. This factor will largely determine the proportion of the high-boiling part of the oil and will influence the composition of the terpene portion, because some of the terpenes suffer a change at higher temperatures.

(3) The length of time used in the distillation. This factor will influence only the proportion of high-boiling oil.

Yield of oil.—In the first seven samples examined considerable difference was found in the oil content. While there may be a certain amount of variation shown by the individual samples in this respect, it is thought that the differences found are more directly connected with the age of the resin. As previously noted, Schimmel & Co. state that the yield of oil is from 15 to 30 per cent. In several cases where I have examined samples of fresh, soft, resin purchased in Manila, I have always found the total yield to be from 25 to 30 per cent of the weight of the resin.

THE PROXIMATE ANALYSIS OF PHILIPPINE COALS.

By Alvin J. Cox.
(From the Chemical Laboratory, Bureau of Science.)

Very few data exist on the relationship between the external appearance and the properties of coal; although we know that a dull coal is apt to be much higher in ash than a lustrous one, and shale, clay fragments and similar impurities are readily detected and removed. Stillman[1] says, regarding the mechanically inclosed earthy matter or other ash-forming material: "It is found in practice that coal from the same vein varies in composition with the size of the coal, the percentage of ash increasing as the size of the coal diminishes." He gives analyses of samples collected from the Hanto Screen building of the Lehigh Coal and Navigation Company, Pennsylvania, from which he formulated this general tendency. A corresponding change in specific gravity would probably also have been noted had attention been given to this fact. Perhaps in time some more closely drawn lines of comparison may be forthcoming, but as yet we do not know enough about the connection between the other external characteristics and the composition of a coal to find these factors of much practical value. At present, nothing short of an analysis will satisfy coal investigators.

An elementary analysis of a coal is of very great importance for scientific purposes, but it shows us little with regard to its value as a fuel. For practical purposes a proximate analysis—that is, the determination of moisture, volatile combustible matter, fixed carbon, ash and sulphur—is of more importance. The figures so obtained give us a very good idea of the real nature of the coal. The moisture and ash are diluents, but more than that, the vaporization of the water entails a considerable loss of heat and the ash hinders complete combustion. The latter fact is shown clearly by the test of Polillo coal[2] at the Insular Cold Storage and Ice Plant, where an analysis of the ash showed it to contain 62.6 per cent of combustible matter. The heat which the ash contains when dropped through the grate constitutes another loss; clinkers formed from the iron and silica of the ash hinder the draft;

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[1] Stillman, T. B.: *Engineering Chemistry*, Easton, Pa. (1900), 25.

[2] *The Far Eastern Review*, Manila and Shanghai (1906), Jan.

sulphur has very little heating value and will in time ruin the grate bars and the boiler. The estimation of volatile combustible matter and of fixed carbon is of great importance, for the relation which exists between these is a means of classification[3] and a criterion for judging the steaming quality of a coal. The percentage of volatile combustible matter gives us some idea of the gas-producing power of the coal and from the residual fixed carbon we are able to know whether the coal is coking or non-coking. It remains for us to seek out the best method of estimating these factors.

The coals of the Philippine Islands which have thus far been discovered are all non-coking. They belong to a class which was of less importance when the directions for coal analysis recommended by the committee appointed by the American Chemical Society[4] were made. These directions are in general use throughout the United States and as they embody the best factors of all previous research upon the proximate analysis of coal, no further discussion of the literature will be entered into. However, since the appearance of these directions non-coking coals have come much to the front and an accurate and uniform method for their analysis is now necessary. The point where the suggestions of the committee are least applicable is in the estimation of the volatile combustible matter.

The method outlined by them for this determination is as follows:

> Place 1 gram of fresh, undried, powdered coal in a platinum crucible weighing 20 to 30 grams and having a tightly fitting cover. Heat over the full flame of a Bunsen burner for seven minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 centimeters above the top of the burner The flame should be fully 20 centimeters high when burning free, and the determination should be made in a place free from drafts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon. To find volatile combustible matter subtract the per cent of moisture from the loss found here.

In a recent paper[5] on "Philippine Coals and their Gas-Producing Power," when discussing certain analyses the following paragraph, which shows that the above directions give uncertain results in the determination of volatile combustible matter in Philippine coals, appeared:

> The coal analyses were made according to the directions recommended by the committee appointed by the American Chemical Society. In the determination of volatile combustible matter, it has been found that in following these very inaccurate results were obtained. The committee states that the most serious objection brought against their method is that the rapid heating causes mechanical

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[3] Hilt, C.: *Jahresb. ueber die Fortshritte d. Chem.* (1873), 1086. "It is necessary for the present at least that the classification of our coals be made on a basis involving the relation of the volatile and the fixed combustible matter, since we have no data other than proximate analyses."

[4] *J. Am. Chem. Soc.* (1899), **21**, 1116; The Coal & Metal Miner's Pocket Book, 7th ed. (1902), Scranton, Pa., 173.

[5] Cox, A. J.: *This Journal* (1906), **1**, 890.

loss in the case of certain non-coking coals; that no evidence has been given as to the amount of such loss, while in the light of certain experimental determinations which are described, they state that the loss can only have been insignificant. It has been observed in this laboratory that the error from this source on our coals is very large, possibly amounting to a few per cent in some cases. It has also been found that this error could be largely if not entirely eliminated by expelling the moisture and most of the volatile matter at a low heat before subjecting to the full flame of the Bunsen burner for seven minutes. Four to five minutes gentle heating are sufficient to do this. With this exception the official method has been followed in detail."

Since the above article went to press, a paper[6] entitled "Some Experiments on the Determination of Volatile Combustible Matter in Coals and Lignites" has reached us, in which the modification used by the fuel-testing plant of the United States Geological Survey in the analysis of lignitic and sub-bituminous coals is described. It is almost identical with the one we have used in the analysis of the coals occurring in these Islands when the official method is inapplicable. The modification which we have heretofore employed is substantially as follows:

> The sample of coal to be analyzed is placed in a platinum crucible of twenty or thirty cubic centimeters capacity and subjected to a low heat, just enough to expel the volatile combustible matter at such a rate that it will burn in a very small flame at the edges of the crucible lid. The heat is regulated by holding the burner in the hand and directing it upon the bottom of the crucible. The flame is slowly moved back and forth under the crucible, the heat is gradually increased as the escaping gases burn lower and lower and finally the crucible is heated for seven minutes over the regulation Bunsen flame.[7]

This method is obviously an improvement in certain cases and was used as a provisional or tentative one until time could be found to investigate the subject thoroughly.

My data do not agree with the statement of the Committee on Coal Analysis that the error due to rapid heating is insignificant. They show that there is a very large mechanical loss when the official method is applied to certain Philippine Coals, confirming the results of experiments on American non-coking coals. It is not even necessary to have analytical data to prove that there are mechanical losses from some non-coking coals when the volatile matter is rapidly expelled, as it is by the official method, for it is amply indicated by the shower of incandescent carbon particles which are driven off during the first one or two minutes heating. It is hoped that this paper will demonstrate how these losses can be avoided.

Somermeier,[8] in referring to the modified process of the fuel-testing plant, says: "The difference in results obtained by three, four and five minutes' preliminary treatment is small and in all subsequent experimental tests the time of the preliminary heating was four minutes." The experiments which follow will show that with some Philippine coals a longer period of preliminary treatment is necessary to give very accurate results. In the coals tested, the determinations of the volatile combustible matter are given as ascertained by the official method and two others, with are intended to avoid the quick application of heat and therefore the loss which ensues in some Philippine coals. The two methods are the one above described, which I have called our transition method, and another which consists in a smoking off process; that is, one which subjects the sample to a low heat, which is regulated by slowly moving a small flame back and forth under the crucible, the flame being just enough to keep a visible amount of smoke rising from the crucible but not sufficient to cause the smoke to burn at the edges of the crucible. It is important that the crucible should not be allowed to cool after the operation has been begun, as in that case air would be drawn in to the coal, which would cause the oxidation of a part of the fixed carbon. The most delicate stage is the one when the hydrocarbons have practically all been expelled and only hydrogen is still being liberated. At this point it is very difficult to drive off the gas slowly enough to prevent its ignition, for the smoke then no longer serves as a gauge. If the gas ignites, it is usually coming off fast enough to carry with it some of the solid carbon particles, as will at once be seen by the sparks; however with care and practice this can be controlled. Since the eye of the operator is the only criterion, no definite time is prescribed for this preliminary treatment, but seven to nine minutes are ordinarily necessary for its completion; in one extreme case sixteen minutes were required. However, it is not a question of an extreme amount of time but of putting the time in the right place. The volatile matter should be smoked off as fast as allowable so as not to produce sparks, but not fast enough for the gases to burn. When this process is completed, without disturbing the crucible, the platinum triangle and crucible are quickly placed over the regulation Bunsen flame and gradually lowered until they are finally in position. These conditions should be maintained as nearly as practicable.

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[6] Somermeier, E. E.: *J. Am. Chem. Soc.* (1906), **28**, 1002.

[7] By the regulation Bunsen flame I understand one which, when nonluminous and unobstructed, burns 20 centimeters high.

[8] *Loc. cit.*

There are times when it is very difficult to make the gas of this laboratory conform to the requirements of the regulation flame. It has been the writer's practice to use a shield to protect the flame of the Bunsen burner from air currents, since the condition of the Committee on Coal Analysis, that "the determination should be made in a place free from drafts," is not easily attained in a laboratory in the Tropics. That this is of minor importance when the regulation flame is carefully maintained is shown by the following experiment. Four samples of thoroughly mixed, non-coking coal were weighed out and carefully smoked off. Nos. 1 and 2 were finally heated for seven minutes over the full flame of a Bunsen burner in a place free from drafts, while 3 and 4 were heated for the same length of time over the flame inclosed in a cylindrical asbestos shield. With this exception the samples received the same treatment in detail. The results are as follows:

	(1)	(2)	(3)	(4)
Total volatile matter, per cent	50.27	50.22	50.26	50.21

A very satisfactory shield is that shown in the figure. It is 12 centimeters long and 6 centimeters in diameter. The platinum triangle is placed on top of the shield so that only about half of the crucible is surrounded. The height of the crucible from the top of the burner is controlled by the cubical blocks.

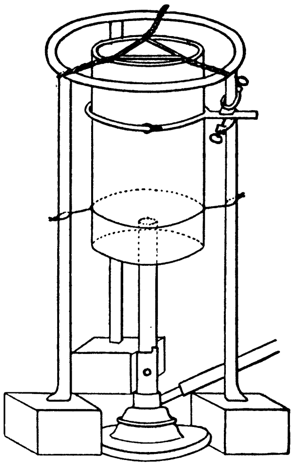

FIG. 1.

In all of the following experiments, platinum crucibles of 20 cubic centimeters' capacity and weighing 20 grams were used. The crucible covers must fit perfectly, but this is always possible since the edges of a crucible can be hammered smooth and round on a cone and the lids can be pressed into shape by placing the top down on a flat ground surface. The coal was pulverized to pass a sixty-mesh sieve. Where determinations of the ash are given, they were made on the same portion of the coal as was used for the volatile matter, consequently mechanical losses are indicated by variations in the percentage, for determinations of the ash admit of great accuracy if performed with due care.

The first sample, an air-dried coal from the southeastern end of *Batan Island,* No. 4, gave the following results:

By the official method:	Per cent.			
Moisture	15.41	15.42	(15.42)	(15.42)
Volatile combustible matter	41.52	41.83	43.05	41.73
Fixed carbon		38.95	37.75	
Ash		3.80	3.78	
		100.00	100.00	

By the transition method:			
Moisture	(15.42)	(15.42)	(15.42)
Volatile combustible matter	40.50	40.26	40.38
By the smoking-off process:			
Moisture	(15.42)	(15.42)	(15.42)
Volatile combustible matter	39.12	39.46	39.45
Fixed carbon	41.35	41.00	41.02
Ash	4.11	4.12	(4.11)
	100.00	100.00	100.00

In choosing the next sample with which to experiment, one very high in impurity was selected, so that extremely small mechanical losses could be noted by a variation in the percentage of ash. This, an air-dried coal from *Negros*, No. 21, gave the following results:

	Per cent.			
By the official method:				
Moisture	18.19	18.29	(18.24)	(18.24)
Volatile combustible matter	38.73	39.13	40.45	41.91
Fixed carbon	26.57	25.90	25.54	
Ash	16.51	16.68	15.77	
	100.00	100.00	100.00	
By the transition method:				
Moisture	(18.24)	(18.24)	(18.24)	
Volatile combustible matter	32.56	32.66	32.64	
Fixed carbon	31.39	31.39		
Ash	17.81	17.71		
	100.00	100.00		
By the smoking-off process:				
Moisture	(18.24)	(18.24)	(18.24)	(18.24)
Volatile combustible matter	32.03	31.98	32.02	31.97
Fixed carbon	31.77	31.74		
Ash	17.96	18.04		
	100.00	100.00		

There are a great many factors which influence the amount of volatile matter driven off from a sample of coal, namely the size of the grains, the weight of the sample, the condition of the coal—that is, the quantity of moisture, etc.—and the degree and duration of the heat. Notwithstanding these considerations it is generally conceded that under uniform conditions the same operator has little trouble with duplicates in ordinary coal analysis and I wish to show that in the analyses of Philippine coals this is true when the modification methods are used. Even different operators working under prescribed conditions obtain insignificant variations in results. My records show that on June 21 of this year this

Negros coal was analyzed by our transition method and the routine results obtained were as follows:

	Per cent.	
Moisture	18.95	(18.95)
Volatile combustible matter	32.39	32.66
Fixed carbon	31.07	
Ash	17.59	
	100.00	

After making due allowance for the variation in the moisture content, these analyses are almost identical with those given above, obtained by the same method. Furthermore, portions of this sample were given to Mr. P. J. Fox (1) and Mr. L. A. Salinger (2) of this Bureau with directions to determine the volatile combustible matter by the official method and also by the smoking-off process.

A 30 cubic centimeter platinum crucible was used in making these determinations in (1). The variation between a crucible of 20 and one of 30 cubic centimeters hardly affect the process noticeably, except where a mechanical loss is involved.

The results are as follows:

By the official method:[9]

	Per cent. (1)	Per cent. (1)	Per cent. (1)
Moisture	(18.24)	(18.24)	(18.24)
Volatile combustible matter	34.67	36.49	33.44

As one would anticipate, when a larger crucible is used the mechanical losses are not quite so large as in the foregoing determinations; however, about the same variations in the percentage of volatile combustible matter are observed here as in the analyses given above, namely, 3 per cent.

By the smoking-off process:

	Per cent. (1)	Per cent. (1)	Per cent. (2)	Per cent. (2)
Moisture	(18.24)	(18.24)	(18.24)	(18.24)
Volatile combustible matter	32.16	32.21	32.00	32.00
Fixed carbon	31.45			
Ash	18.15			
	100.00			

Here there is almost exact duplication of the previous results obtained by this method.

For the third sample, *Negros coal,* No. 23 was chosen, one very high in ash and the one in which the official and smoking-off methods showed the greatest discrepancies in the percentage of ash.

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[9] The average of my own duplicated water determinations has been used. In a single determination Mr. Fox obtained 18.37 per cent.

The analyses are as follows:

By the official method:

	Per cent.	
Moisture	15.81	15.92
Volatile combustible matter	55.92	54.08
Fixed carbon	18.60	19.76
Ash	9.67	10.24
	100.00	100.00

By the smoking-off process:

Moisture	(15.86)	(15.86)
Volatile combustible matter	35.48	35.56
Fixed carbon	34.42	34.36
Ash	14.24	14.22
	100.00	100.00

From the foregoing experiments it is possible to point out the mechanical losses. We will assume the ash obtained by the smoking-off process to be correct, for in these determinations no escaping particles of solid carbon were at any time visible. The averages of the analyses, studied comparatively, are as follows:

SAMPLE I.

	By the smoking-off process. Per cent.	By the official method. Per cent.
Ash	4.11	3.79
Fixed carbon	41.13	38.35

From these we get the ratios $\frac{4.11}{3.79}=1.08$ and $\frac{41.13}{38.35}=1.07$ which show that the variations in the percentage of ash and fixed carbon are approximately proportional. The ash content however is too small to be an indicator of small differences.

SAMPLE II.

	By the smoking-off process. Per cent.	By the transition method. Per cent.	By the official method. Per cent.
Ash	18.00	17.76	16.60
Fixed carbon	31.75	31.39	26.24

The first two columns give the ratios $\frac{18.00}{17.76}=1.01$ and $\frac{31.75}{31.39}=1.01$ which show that the variations between the ash and fixed carbon in the two processes are exactly proportional. The first and last columns give the ratios $\frac{18.00}{16.60}=1.08$ and $\frac{31.75}{26.24}=1.21$. Here the ratios are not exactly proportional.

SAMPLE III.

	By the smoking-off process. Per cent.	By the official method. Per cent.
Ash	14.23	9.95
Fixed carbon	34.39	19.18

These give the ratios $\frac{14.23}{9.95}=1.43$ and $\frac{34.39}{19.18}=1.79$, and show that here also the variations in the percentage of ash and fixed carbon are not exactly proportional.

In the determinations made by the transition method the escape of some of the incandescent particles was noticeable but it has been thought that this was negligible. The above experiments show this to be a false supposition; that for very accurate work more care must be exercised than is outlined for that method. Since the variations between the percentages of ash and fixed carbon as determined by the smoking-off process and the transition method are exactly proportional the cause must be solely mechanical loss.

As previously stated, the shower of sparks driven off when the official method is used is proof of a large mechanical loss; the analytical data which corroborate this, show that it is several per cent. The variations in ash and fixed carbon as determined by the smoking-off process and the official method in samples I, II, and III are always in the same direction, but are not exactly proportional and hence can not be accounted for solely by the theory of mechanical loss. Other factors prevent proportional variations. It has been suggested[10] that this may be partially due to a different breaking down of the hydrocarbon compounds when expelled under different conditions of heat treatment, in the presence of variable amounts of moisture, etc. This is true in the case of coking coals for it has often been observed that both the qualitative and quantitative composition of coke depends not only on the nature of the coal used but also on the conditions of the distillation that is, the temperature, pressure in the retort, the time, the size of the coal, etc. However, in lignities and noncoking coals, where the gases given off are mostly of comparatively very simple composition, the variation between the official and the modified methods is to a greater extent due to mechanical loss.

Comparisons of a number of samples will show more clearly just how much difference really exists in the breaking down of the hydrocarbon compounds of the coal. The difference shown in the breaking down between the transition method and the official one is the same as between the smoking-off process and the official method, since the variations in the percentage of fixed carbon and of ash as determined by the transition method and the smoking-off method are exactly proportional. The transition method is an improvement over the official one in certain cases but as there still are mechanical losses by its use, it is set aside as less satisfactory than the smoking-off process.

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[10] Somermeier E. E.: *Loc. cit.*

TABLE I.—*List and classification of the coals used in this investigation.*

No.	Source.	Predominating fracture.	Peculiarity of structure.	Specific gravity.[a]	Luster.	Color.	Color of powder (60 mesh).
1	Australia[b]	Hackly		1.29	Dull to lustrous; uneven; weathered surface silky.	Black	Brownish black.
2	do.[b]					do	Black with a tinge of brown.
3	do	Hackly for the most part	Characterized by alternating dull and lustrous bands.[c]	1.38	Dull for the most part; silky; streak very lustrous.	do	Do.
4	Batan Island, Bett's	Hackly and conchoidal	Locally there is a tendency to fall apart into cubes.	[d]1.38	Sublustrous; uneven	do	Do.
5	Batan Island, military reservation; coal seam, No. 5.	Hackly	Fairly compact, pseudo-oölitic.	1.31	Lustrous	do	Shiny black.
6	Batan Island, military reservation; Big Tree seam tunnel.	do		1.32	do	do	Do.
7	Batan Island[e]	Conchoidal		1.34	Sublustrous	do	Do.
8	do.[e]	Hackly		1.44	Dull	Black with a tinge of brown.	Brownish black.
9	Cebu, near Alegria	do	Pronounced cleaveage parallel to the bedding planes.	1.34	Very dull	Dark brown	Brown.
10	Cebu, near Balamban	do		1.30	Lustrous	Black	Brownish black.
11	Cebu, near Carmen	Conchoidal		1.30	do	do	Black with a tinge of brown.
12	do	Hackly for the most part		1.35	Sublustrous	do	Do.
13	do	Conchoidal		1.33	Lustrous	do	Do.
14	do	do		1.33	do	do	Do.
15	Cebu, near Compostela	Hackly	Contains elliptical pitlike markings.[f]	1.27	Lustrous, uneven	do	Do.
16	Cebu, Libingbato	do		1.29	Lustrous	do	Do.
17	Cebu	Conchoidal		1.33	do	do	Shiny black.
18	Japan, Kishima	Hackly	Compact; pseudo-oölitic.	1.31	do	do	Do.

19	Luzon, Rizal	Conchoidal		1.37	Lustrous	do	Do.
20	Mindoro, Bulalacao	Hackly		1.38	Sublustrous	do	Black.
21	Negros, near Cadiz	Conchoidal	Cleats very pronounced; breaks with a degree of regularity.	1.39	Dull to sublustrous	Dull black	Very dark brown.
22	Negros, Escalante	Hackly for the most part		1.34	Sublustrous to lustrous	Black	Shiny black.
23	Negros	Conchoidal and hackly	Pseudo-oölitic [g]	1.43	Dull to very lustrous; uneven.	do	Black.
24	Polillo	Hackly	Slickensides	1.34	Dull to lustrous	do	Black with a tinge of brown.
25	Polillo, Visita de Burdeus	do		1.29	Sublustrous; uneven	do	Do.
26	Polillo					do	Do.
27	do					do	Do.
28	Philippines [h]	Hackly			Sublustrous	Black with a tinge of brown.	Dark brown.
29	do. [h]	do		1.34	Sublustrous to lustrous	Black	Black.
30	do. [h]	do		1.32	Sublustrous	do	Black with a tinge of brown.
31	Samar, Paranas	Conchoidal		1.25	Lustrous	do	Do.
32	Samar						Dark brown.
33	Surigao	Conchoidal and hackly	Locally pseudo-oölitic	1.38	Sublustrous; uneven	Black	Shiny black.
34	Tayabas, Antimonan	Hackly		1.34	Dull to lustrous	do	Black with a tinge of brown.
35	Tayabas, Mauban	do		1.81	Very dull	Black with a tinge of brown.	Brownish black.
36	Wyoming, Rock Springs	do		1.27	Sublustrous	Black	Black.
37	Zamboanga			1.32	Lustrous	do	Shiny black.

[a] Determined with a Joly balance.

[b] Laboratory supply.

[c] The lustrous bands are usually not over 3 or 4 millimeters in thickness, while the dull layers are many times that. There is a parting along the bedding planes and also one at right angles to this, following the cleat, the latter being more pronounced.

[d] Variable.

[e] Outcrop coals.

[f] Mr. W. D. Smith suggests that the pit-like markings may possibly represent scars on the bark of some tertiary plants similar to the markings on the tree ferns existing in the Philippines at the present time. These, as far as known, are characteristic of the Compostela coal only.

[g] This coal does not seem to be in its original condition, but there are indications that it has undergone chemical change. It is probable that some sort of slow fractional distillation has taken place. The coal gives scarcely any smoke when subjected to the full heat of a Bunsen burner, although the percentage of volatile combustible matter which consists mostly of methane and hydrogen is of average amount. The fracture is also peculiar. It breaks up first into lumps exhibiting conchoidal faces. On further breaking, the fracture is granular and very minute, thus giving rise to many reflecting surfaces.

[h] Exact source unknown.

TABLE 2.[a]—*Comparative analyses.*

No.	Source.	Official method, per cent.				Smoking-off method, per cent.			Color of ash.	Total sulphur.	Fuel ratio.[b]	
		Water.	Volatile combustible.	Fixed carbon.	Ash.	Volatile combustible.	Fixed carbon.	Ash.			Official method.[c]	Smoking-off method.[d]
1	Australia[e]	2.53 2.53	36.12 36.07	48.99 48.96	12.36 12.44	33.67 33.47	51.27 51.44	12.53 12.56		0.09	1.357	1.530
2	do.[e]	2.59 2.69	32.85	52.97	11.59	29.93 30.43	55.90 55.34	11.58 11.54	White		1.613	1.844
3	do	1.26 1.25	25.26 25.26	63.39 63.60	9.88 10.10			(9.99) (9.99)			2.474	
4	Batan Island, Bett's	15.41 15.42	41.74 41.83	39.05 38.97	3.80 3.78	39.46 39.46	41.02 41.00	4.11 4.12		0.22	0.933	1.040
5	Batan Island, military reservation; coal seam No. 5.	7.42 7.47	45.62 45.33	45.01 45.24	1.95 1.96	35.15 35.36	44.96 44.67	2.47 2.50	Yellow brown	0.25	0.992	1.271
6	Batan Island, military reservation; Big Tree seam tunnel.	Official method applicable; very slight mechanical loss.										
7	Batan Island	Large mechanical loss by the official method.										
8	do.[f]	12.50 12.53	39.96 40.81	33.08 32.44	14.46 14.22	35.68 35.69	37.12 36.94	14.70 14.84	Cream to brown	0.83	0.799	1.037
9	Cebu, near Alegria	Large mechanical loss by the official method.										
10	Cebu, near Balamban	Official method applicable										
11	Cebu, near Carmen	14.61 14.71	50.80 52.18	33.40 31.90	1.19 1.11	35.58 35.43	48.16 48.29	1.65 1.57	Reddish	0.12	0.634	1.358
12	do	14.38 14.33	41.37	37.07	7.18	38.35 37.75	39.96 40.28	7.31 7.64	Reddish brown	1.70	0.898	1.055
13	do	13.51 13.38	48.95	32.09	5.45	35.58 34.90	44.49 45.13	6.42 6.59	Yellow	0.23	0.656	1.272
14	do	15.71 15.65	48.81	32.66	2.82	35.48 35.30	45.58 45.72	3.23 3.33	Buff	1.05	0.670	1.290
15	Cebu, near Compostela[g]	Official method applicable; no mechanical loss.										

16	Cebu, Libingbato[f]	4.86 4.87	43.20 43.57	47.87 47.46	4.25 4.10	36.44 36.59	54.58 54.50	4.12 4.04	Brown and pink	1.88		
17	Cebu	12.29 12.31	42.96	41.07	3.68	36.84	47.06	3.81	Brown	0.04	0.956	1.278
	do.[f]	12.40 12.26	44.44 44.08	39.46 40.02	3.62 3.64	36.79 36.86	46.84 46.88	3.97 4.00		(0.04)	0.898	1.244
18	Japan, Kishima	Mechanical loss by official method										
19	Luzon, Rizal[f]	7.96 8.22	41.74 43.06	44.30 43.00	6.00 5.72	36.61 36.41	49.29 49.40	6.15 5.97		0.74	1.030	1.352
20	Mindoro, Bulalacao	10.84 10.70	44.18	43.54	1.44	39.70 39.41	47.84 48.27	1.62 1.61	Yellowish red		0.987	1.215
21	Negros, near Cadiz	18.19 18.29	38.73 39.13	26.57 25.90	16.51 16.68	32.03 31.98	31.74 31.77	18.04 17.96	White	0.00	0.674	0.989
22	Negros, Escalante[f]	12.97 13.00	43.39 43.14	34.10 34.52	9.54 9.34	37.13 37.29	30.32 30.29	9.58 9.42		1.67	0.800	0.813
23	Negros	15.81 15.92	55.92 54.08	18.60 19.76	9.67 10.24	35.53 35.50	34.42 34.36	14.24 14.22	Dark brown	0.99	0.349	0.969
	do.[f]	15.90 15.68				35.44	34.37	14.29 14.31		(0.99)		0.969
24	Polillo	5.88 5.90	42.64 42.64	45.49 45.48	5.99 5.98	39.18 39.39	48.90 48.75	6.04 5.96	Red		1.040	1.240
25	Polillo, Visita de Burdeus[g]	5.50 (5.50)	44.05 44.15	46.07 45.97	4.38 (4.38)	Official method accurate					1.044	
26	Polillo[h]	4.36 4.51	44.20 44.35	47.58 47.40	3.86 3.74	39.32 39.49	52.42 52.30	3.90 3.70	Red		1.073	1.327
27	do	5.62 5.62	40.06 40.23	42.73 42.56	11.59 (11.59)	37.83 37.84	44.96 44.83	11.59 11.71	do	0.27	1.063	1.186
28	Philippines[i]	16.34 16.35	45.30 45.64	30.33	8.03	43.87 43.94	31.75 31.82	8.04 7.89	Reddish white		0.666	0.724
29	do.[g] [i]	6.90 (6.90)	42.10 42.40	43.78 43.48	7.22 (7.22)	Official method accurate					1.033	
30	do.[h] [i]	6.76 (6.76)	41.72 41.76	44.57 44.53	6.95 (6.95)	Official method accurate					1.067	
31	Samar, Paranas	9.01 9.13	42.02	45.56	3.41	39.76 40.06	47.75 47.31	3.48 3.50	Red		1.083	1.192

[a] This table includes the analyses of the three coals specifically mentioned above.

[b] $\frac{\text{Fixed carbon.}}{\text{Volatile combustible.}}$

[c] Calculated from analyses by the official method.

[d] Calculated from analyses by the smoking-off method.

[e] Coking.

[f] Analyzed by Mr. L. A. Salinger.

[g] Semi-coking.

[h] Incipient coking.

[i] Exact source unknown.

TABLE 2.—*Comparative analyses*—Continued.

No.	Source.	Official method, per cent.				Smoking-off method, per cent.			Color of ash.	Total sulphur.	Fuel ratio.	
		Water.	Volatile combustible.	Fixed carbon.	Ash.	Volatile combustible.	Fixed carbon.	Ash.			Official method.	Smoking-off method.
32	Samar[a]	15.24 15.26	46.95 46.96	34.97 34.70	2.84 3.08	45.38 45.29	36.36 36.40	3.02 3.05	Reddish white		0.742	0.803
33	Surigao[b]	13.17 13.21	47.57 48.07	31.26 30.78	8.00 7.94	39.88 39.94	37.80 37.87	9.15 8.98	Brown		0.648	0.948
34	Tayabas, Atimonan	12.21 12.33	46.10	37.96	3.73	44.66 44.80	39.43 39.18	3.70 3.69	Yellow		0.324	0.879
35	Tayabas, Mauban[b]	9.93	29.35	29.02	31.70	26.87	30.80	32.40	Red to gray	0.45	0.990	0.948
36	Wyoming, Rock Springs[b]	9.84 9.74	39.38 39.02	49.10 49.47	1.68 1.77	32.44 32.48	55.86 55.80	1.86 1.96			1.257	1.718
37	Zamboanga[c]	6.23 6.47	43.55	46.43	3.79	39.27 39.32	50.72 50.45	3.78 3.76	Red	0.06	1.067	1.287

[a] Incipient coking.

[b] Analyzed by Mr. L. A. Salinger.

[c] Semi-coking.

Leaving out of consideration those coals in which there is a discordance in the percentage of ash as determined by the two methods, we can draw some conclusions from the analyses.

By a selection there are fourteen samples which show no or only very slight mechanical losses when analyzed by the official method. In these the deviation in the percentage of volatile combustible matter and therefore of fixed carbon is due entirely to the difference in the breaking down of the volatile constituents of the coal. When arranged in the order of the decreasing variation of the percentage of fixed carbon as determined by the official method and the smoking-off process they fall into two groups as follows:

TABLE 3.

Number and group.	Source of coal.	Difference in per cent.
Group I:		
26	Polillo	4.87
3	Australia	4.57
37	Zamboanga	4.16
8	Batan Island	4.12
24	Polillo	3.34
12	Cebu	3.05
2	Australia	2.65
1	do	2.33
27	Polillo	2.25
Group II:		
4	Batan Island[11]	2.00
31	Samar	1.97
32	do	1.55
28	Philippines	1.45
34	Tayabas	1.34

The difference in the amount of fixed carbon depends both on the amount of the volatile ingredients in the coal and on the nature of these volatile compounds. The first factor is approximately the same in Philippine coals,[12] and therefore the cause of the variation is to be sought in the nature of the volatile compounds. We well know that volatile ingredients of similar composition may differ to a considerable extent in volatility and afford entirely different products on destructive distillation and that it is impossible chemically to formulate this change; nevertheless, judging from the analyses of some of the gases we should expect the difference in the breaking down of the volatile ingredients under the different heat treatments of the two methods to be about as it is. The more complex the volatile matter, the greater the disparity to be looked for in the results of analyses by the official and the smoking-off methods.

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[11] This was taken from the southeastern end of the island. It is a well-known fact that the coals from this region are of a much poorer grade than those from the western end where the military reservation claims are located.

[12] Cox, A. J.: *Loc. cit.*

The official method of analysis is applicable to almost all of the coals of the class of *Group I*. They give a volume of dense smoke when subjected to the influence of heat. The gas produced by destructive distillation from three of the coals of *Group I* has been analyzed as follows:

TABLE 4.

[The figures give percentages.]

No.	Source of the coal.	Carbon dioxide (CO_2).	Heavy hydrocarbons (C_nH_{2n}).	Oxygen (O_2).	Carbon monoxide (CO).	Methane (CH_4).	Hydrogen (H_2).	Nitrogen (N_2).
37	Zamboanga	10.1	**6.2**	0.65	9.5	35.5	36.4	1.65
24	Polillo	8.4	**8.1**	0.7	8.95	32.7	40.5	0.65
1	Australia	6.24	**6.34**	0.73	5.03	42.05	37.34	2.17

The official method of analysis is only rarely applicable to the coals of the class of *Group II*. Even the result given for the Batan Island sample which heads the column is too large, owing to mechanical loss of fixed carbon and ash in the estimation of the volatile matter by the official method. Practically all of the coals in *Table 2* not included in *Group I* would be incorporated in *Group II* except for the large mechanical losses. In the extreme case of *Negros* No. 23 these amount to 10 or 12 per cent. The volatile matter which is expelled by the quick application of heat is in general of a light color and in certain cases colorless. The gas produced by destructive distillation from two coals of *Group II* has been analyzed as follows:

TABLE 5.

[The figures give percentages.]

No.	Source of the coal.	Carbon dioxide (CO_2).	Heavy hydrocarbons (C_nH_{2n}).	Oxygen (O_2).	Carbon monoxide (CO).	Methane (CH_4).	Hydrogen (H_2).	Nitrogen (N_2).
4	Batan Island	26.04	**2.31**	0.43	14.15	16.9	35.4	4.77
21	Negros	17.44	**3.21**	0.05	7.15	34.43	34.48	3.24

Tables 4 and *5* show that the heavy hydrocarbon content of the gases produced from the coals of *Group I* is about three times as large as that from the coals of *Group II; Table 3* shows that the difference in the results for fixed carbon obtained by the official and the smoking-off methods in the analyses of the coals is much greater in *Group I* than in *Group II;* hence it is evident that this difference varies with the complexity of the volatile constituents of the coal—that is, that the variation is due largely to the difference in the breaking down of the volatile ingredients. The data given in *Table 3* indicate that the difference in

the results obtained by the two methods on coals of the Negros and Cebu type[13] (*Group II*) for fixed carbon average about one and a half per cent; as a matter of fact however, the numbers given are undoubtedly larger than the average would be were it possible to eliminate the factor of mechanical loss and obtain a larger and more representative number of coals.

Table 2 and the tables of analyses of Philippine coals which have already been published[14] show that the content of water varies from 5 to 20 per cent. In a number of cases this does not represent water of constitution only, but since the samples are direct from the mine it includes a considerable percentage of loosely held water. This latter is a varying factor and within wide limits is not definite for any particular coal. Attention has already been called to the absurdity of trying to classify coal according to its water content.[15] It might perhaps be said that the more lignitic the character of the coal, the greater the possibility of its including a large percentage of water, but in general the percentage varies with the exposure of the coal, the season of the year, and the state of the weather. It, then, is very important to know what influence, if any, the presence of water has upon the accurate estimation of the volatile combustile matter. To ascertain this the following series of determinations were made by the smoking-off process, with the three samples. To the weighed samples of *Batan Island* coal and of the *Negros* coals definite amounts of water were added and thoroughly mixed in with a fine plantinum wire. The results are as follows:

TABLE 6.

Grams water added per gram of coal.	Total volatile matter, per cent.				
	Batan Island coal No. 4.		Negros coal No. 21.		Negros coal No. 23.
	1.	2.	1.	2.	
0.00	54.88	54.87	50.22	50.26	51.34
0.05	----------	----------	50.08	----------	----------
0.10	54.96	[16]55.15	50.22	50.27	51.42
0.15	----------	----------	50.10	----------	----------
0.20	54.95	54.97	50.34	50.17	----------
0.30	54.83	[16]55.27	50.22	50.27	----------

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[13] The striking similarity in both the physical and the chemical behavior of coals from Negros and Cebu has been constantly in evidence throughout this investigation. Mr. W. D. Smith informs me that all the geology indicates that these two islands are anticlines and that the separating Strait of Tañon occupies the syncline.

[14] Cox, A. J.: *Loc. cit.* 880–884.

[15] Idem: *Loc. cit.*, 885.

[16] A 30 cubic centimeter crucible was used in making these determinations and the results are slightly higher owing to the larger surface on which carbon was deposited.

Still another sample of *Negros* coal No. 21 was dried at 107° for one hour and the total volatile matter determined to be 50.22 per cent.

These results show that owing to the very gradual expulsion of the moisture by the smoking-off process, the presence of water in these coals has no influence on the percentage of volatile combustible matter. The only effect noticed was that the presence of the water very much reduced the tendency of the fine particles to fly off in sparks. The loss by the official method was eliminated in some cases when a small amount of water was mixed with the coal.

The analyses by the official method of *Negros* coal No. 21, given on page 46, show an average of the total volatile matter of 57.68 per cent, and at the same time a great discordance due to mechanical loss, as is indicated by the low percentage of ash. When water in the amounts given in the following table is added and thoroughly mixed with a platinum wire or spatula the results are as shown below. It was thought that there might be a difference in the results if a spatula were used instead of a wire, owing to the fact that with the former the water could be more perfectly introduced into the interstices of the coal.

TABLE 7.

When the mixing was done with a wire.

Grams water added per gram of coal.	Total volatile matter, per cent.	Ash, per cent.	Average.	
			Total volatile matter, per cent.	Ash, per cent.
0.00	56.92 57.42 58.69	16.51 16.68 15.77	57.68	16.32
0.05	52.25 52.34	17.63 17.68	52.30	17.66
0.1	52.59 52.50 52.85	17.76 17.65 18.06	52.64	17.82
0.2	53.71 53.90	17.98	53.85	17.98
0.3	52.85	17.80	52.85	17.80

When the mixing was done with a spatula.

Grams water added per gram of coal.	Total volatile matter, per cent.		Ash per cent.	Average.	
	Sers. 1.	*Sers. 2.*		Total volatile matter, per cent.	Ash, per cent.
0.1	-------	51.03	----------	51.39	17.71
	-------	52.42	17.71		
	50.72	-------	----------		
0.2	-------	52.74	17.78	51.64	17.78
	50.54	-------	----------		
0.3	-------	52.55	17.94	52.01	17.94
	51.47	-------	----------		

The results with *Negros* coal No. 23 when analyzed by the official method are as follows:

TABLE 8.

Grams water added per gram of coal.	Total volatile matter, per cent.	Ash, per cent.	Average.	
			Total volatile matter, per cent.	Ash, per cent.
0.00	71.73 70.00	9.67 10.22	70.86	9.99
0.1	54.13	13.28	54.13	13.28
0.2	52.53	14.28	52.53	14.28
0.3	53.62	14.19	53.62	14.19

The cause of variation in these averages when the amount of water is changed can be resolved into two opposing factors. First, the water serves to dampen and hold together the solid particles, thereby preventing mechanical loss. The percentage of ash after the first addition of water increases until, with the addition of about 20 per cent, the value is very close to that obtained by the smoking-off process. Secondly, the water exerts an influence on the decomposition of the coals tending to increase the percentage of volatile matter. *Tables 6* and *7* show that as water is added, the apparent total amount of volatile matter rapidly diminishes until mechanical losses, as shown by the fact that the percentage of ash agrees with that obtained by the smoking-off process, are overcome. On the further addition of water the percentage of volatile matter does not remain constant, as would be the case if the dampening effect were the only factor, but it increases while the percentage of ash does not change. In the beginning and until about 20 per cent of water has been added, the first factor predominates; after this the second is made evident. In order further to show the extent of the action of water, experiments were made with two coals as follows:

TABLE 9.—*Analyses of coals.*

No.	Source of the coal.	Official method.			Smoking-off method.
		Total volatile matter, per cent.	Fixed carbon, per cent.	Ash, per cent.	Ash, per cent.
24	Polillo	48.53	44.92	5.99	6.00
1	Australia	38.63	48.98	12.39	12.54

The duplication in the percentages of ash by the two methods shows that the official method of analysis is accurate when used here. The effect of water in varying amounts on the decomposition of the coal when this method is used is shown by the following numbers:

TABLE 10.—*Polillo coal, No. 24.*

Grams water added per gram of coal.	Total volatile matter, per cent.	Ash, per cent.	Average.	
			Total volatile matter, per cent.	Ash, per cent.
0.0	48.52 48.54	5.99 5.98	48.53	5.98
0.1	49.77 49.61	5.90 5.80	49.69	5.85
0.2	50.19 50.34	---------- ----------	50.26	----------
0.3	50.32	5.89	50.32	5.89

TABLE 11.—*Australia coal, No. 1 (coking).*

0.0	38.60 38.65	12.44 12.36	38.62	12.40
0.05	40.09	----------	40.09	
0.1	40.24	12.38	40.24	12.38
0.2	40.70	----------	40.70	----------
0.3	41.20 40.77	---------- ----------	40.99	----------
0.4	41.60	12.33	41.60	12.33

These samples represent widely different kinds of coal, but the results show that loosely held water in the coals increases the value of the volatile combustible matter by about one and a half per cent. Nearly all of this increase results from the addition of the first 5 per cent of water.

The results shown in *Tables 6, 7, 8, 9, 10,* and *11* give the following figure when expressed as curves:

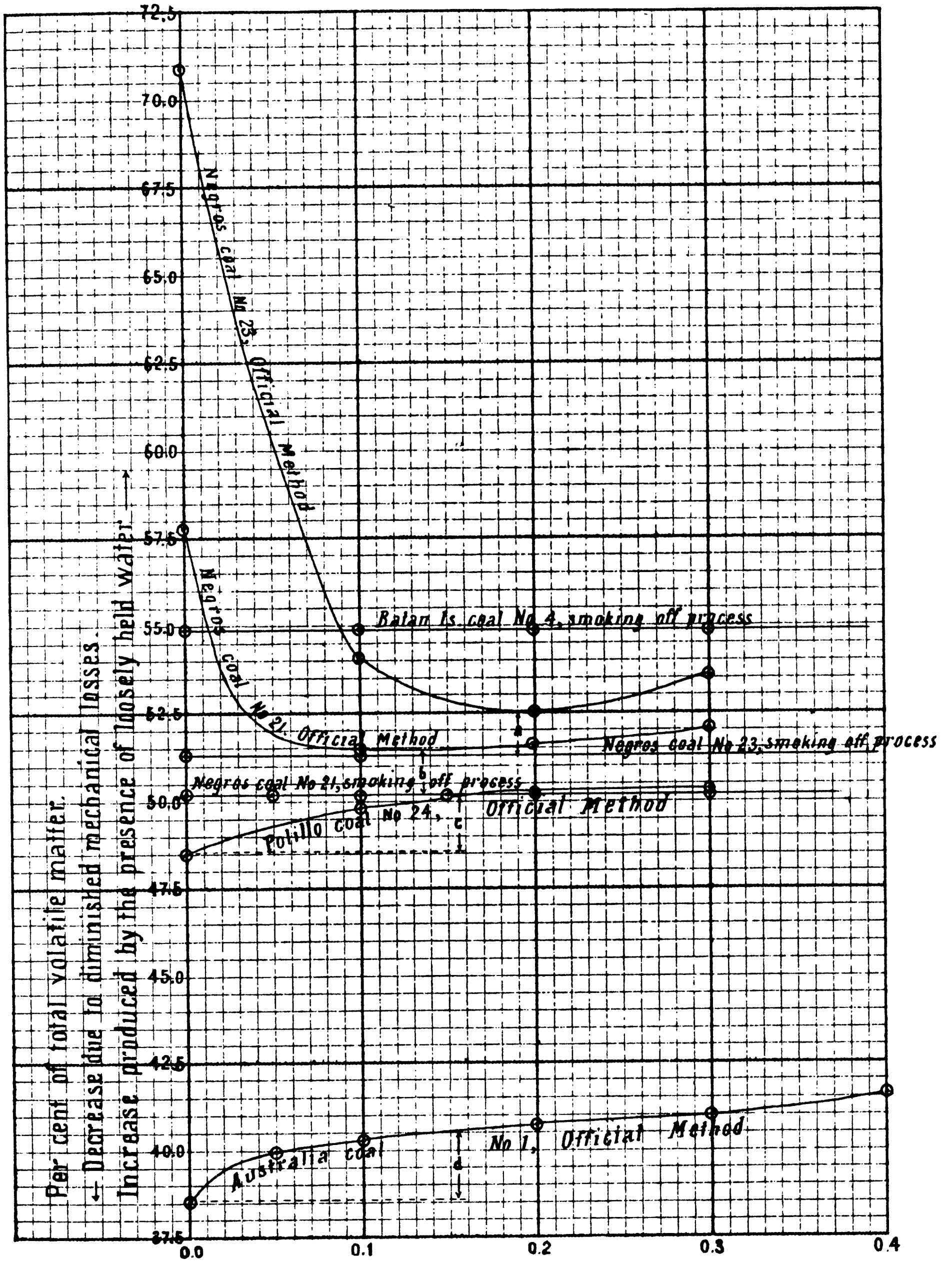
72.5
70.0
67.5
65.0
62.5
60.0
57.5
55.0
52.5
50.0
47.5
45.0
42.5
40.0
37.5
0.0
0.1
0.2
0.3
0.4
Per cent of total volatile matter.
← Decrease due to diminished mechanical losses.
Increase produced by the presence of loosely held water →
Negros coal No 23, Official Method
Negros coal No 21, Official Method
Balan Is. coal No 4, smoking off process
Negros coal No 23, smoking off process
Negros coal No 21, smoking off process
Polillo coal No 24, Official Method
Australia coal No 1, Official Method
a
b
c
d
Grams water added per gram of coal.

FIG. 2.

It will be noticed in the above curves that the differences *a* and *b* represent the sum of *two* factors, the change in results due to the different heat treatment and the deviation due to the presence of loosely held water; *c* and *d* represent only one factor, the deviation due to the presence of water. The alteration of a single condition in the method used in the analysis of coals to which the official method is applicable, as represented by *c* and *d* produces more variation than the combined changes in the method of the analysis of coals which give large mechanical losses by the official method. I have already shown that the effect of water when the official method is used is to increase considerably the percentage of volatile combustible matter in *Negros* coals; hence it must be concluded that the factor represented by *a* or *b* minus this increase—that is, the change in results due to the difference in the breaking down of the hydrocarbons of the coal under the varied heat treatments of the official and the smoking-off methods—is reasonably small.

On the other hand, direct data have been given to show that there is a positive difference. My results give discrepancies between the fixed carbon and ash as determined by the two methods which are not directly proportional and therefore are not due wholly to mechanical losses. Fortunately, this difference due to the varied heat treatments of the two methods is smallest in the case of coals which can only be inaccurately analyzed by the official method; it is also in these coals where large variations in the percentage of moisture are apt to take place. Moisture has no influence on the fuel ratio calculated from results obtained by the smoking-off method, while large variations by the official method in case it were applicable—that is, barring mechanical losses—would be anticipated. Therefore, the variation produced by the altered breaking down of the coal by the different heat treatments in the two methods is probably not greater and perhaps even less than that which would be possible with the official method alone;[17] while with the smoking-off method the mechanical losses are overcome.

In describing the coke ovens of the Colorado Fuel and Iron Company at Segunda, Colorado, Mr. Hosea says:[18] "The larry cars hold 5½ to 6 tons of disintegrated washed coal, and each weighs 12 tons loaded. This is the customary charge for ovens of this pattern, and the charge is coked in forty-eight hours, producing from 3½ to 3¾ tons of coke, or a yield of from 60 to 65 per cent." It is evident from the above that the coal in the furnace is more slowly heated than it is by the official method, although the latter is intended to approach the actual conditions in a coke oven. Probably, by the smoking-off method this is more nearly attained, since seldom more than seven to nine minutes are required to expel the volatile matter. The curves demonstrate clearly that the smoking-off method is more reliable for general use than the official method. Varying quantities of water have no effect with the former while the curves obtained by the latter under similar conditions are more or less variable; therefore, I heartily recommend the smoking-off method for general adoption.

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[17] The results of *Table 10* show that the greatest change in the percentage of fixed carbon is produced by a variation of the loosely held water by not more than 5 per cent. Unless care is exercised such variation may occur while the sample is being taken and during its transportation to the laboratory. Cf. Sommermeier, E. E.: *J. Am., Chem. Soc.* (1906), **28**, 1630.

[18] Hosea, R. M.: *Mines and Minerals* Denver, Colorado (1904), **25**, 8.

In order to ascertain how much of the entire "seven minutes over the full heat of a Bunsen burner" is necessary in the analysis of coal by the official method, the following experiment was made on Australian coal No. 1. About one and a third minutes were required to expel the gases which came off at a rate fast enough to burn. The results indicating the influence on the percentage of total volatile matter when the crucible and sample were subjected to the regulation flame for varying lengths of time are noted below.

Time over the full flame in minutes.	Total volatile matter, per cent.
3	38.65
4	38.50
7	38.65

Furthermore, to determine with the smoking-off process, whether or not the subjection to the full heat of the Bunsen burner for seven minutes is necessary or to what extent essential, a number of experiments were made on *Negros* coal No. 21. The samples were carefully smoked off and then heated over the regulation flame for varying lengths of time as noted below, with the following results:

Time over the full flame in minutes.	Total volatile matter, per cent.	
1	48.53	
3	49.46	
4	50.27	Constant.
5	50.24	
6	50.21	
7	[19] 50.24	

It has already been shown [20] that heating until all gases apparently cease issuing from the crucible is not sufficient. In the experiments with finely powdered coal such a sufficiency was most nearly attained. My results show that by either method the gases are all expelled after four minutes of heating, also that there is no loss on further heating. In the analyses of these particular coals considerable latitude might be allowed.

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[19] The average of four results, the greatest variation of which is 0.06 per cent.

[20] Wright, L. T.: *J. Soc. Chem. Ind.* (1885), 4, 657.

A qualitative experiment will show in a few minutes whether or not a coal suffers mechanical loss by the official method. It has been demonstrated that the latter is thoroughly applicable in the analysis of some of the Philippine coals—that is, to bituminous coals which sinter together and to non-coking coals where there is no mechanical loss—while it is not at all tenable and is just as thoroughly inapplicable in the analysis of certain other native coals. Therefore, the problem of establishing an entirely satisfactory method is not nearly so simple as it was at first thought to be. Any method where a correction is involved is not satisfactory, but it would necessarily have to be used if an attempt were made to formulate a method applicable alike to all the coals of the Archipelago.

For the present, in order to facilitate direct comparison with coals from other sources we shall continue to use the official method in this laboratory wherever it is applicable, but in those cases where it entails large losses we shall employ the smoking-off process, followed by seven minutes over the full flame. The experiments show that less than seven minutes would suffice, but since no loss is entailed by the seven-minute treatment it is well to maintain uniformity. The means of estimating moisture, fixed carbon and ash as outlined by the committee are satisfactory in these non-coking coals, provided the volatile matter is carefully smoked off from that portion on which the ash is determined. The recommendations for the determination of ash are to "burn the portion of powdered coal used for the determination of moisture, till free from carbon. If properly treated, this sample can be burned much more quickly than the dense carbon left from the determination of volatile matter." In the case of non-coking coals there seems to be no difference in the time required, whether the sample used for the determination of moisture or that left from the determination of volatile matter is employed. In fact there is this to be said in favor of the latter that it is all ready to burn; if the former is used it must first be carefully smoked off with the crucible lid on tight to prevent mechanical loss of ash.

If the smoking-off method is used only when the official method shows mechanical loss, it will suffice for commercial work to neglect the difference in the breaking down of the hydrocarbons of the coals by different heat treatment, as is indicated by the data from *Negros* coals Nos. 21 and 23, and to consider the results obtained by the smoking-off process directly comparable with the analyses of coking coals analyzed according to the directions of the Committee on Coal Analysis. If coals, the volatile matter of which is high in heavy hydrocarbon compounds, are analyzed by the smoking-off method then the factor of the difference in the breaking down of these compounds is of sufficient magnitude to demand consideration.

SUMMARY.

(1) The directions for coal analyses recommended by the committee appointed by the American Chemical Society are inapplicable to certain Philippine coals.

(2) These coals are easily detected by the shower of incandescent carbon particles which are driven off when the sample is subjected to rapid heating.

(3) This mechanical loss can be overcome by expelling the volatile matter with sufficient slowness so that the escaping gases do not ignite. This is demonstrated by the fact that when the fixed carbon is burned to ash, the percentage of the latter is much higher than that obtained by the official method.

(4) An increase in the amount of moisture in a coal increases the percentage of volatile combustile matter when the official method is used. When the smoking-off method is applied—that is, when the gases are expelled very slowly—a variation in the amount of water produces no change.

(5) A comparison of the official and the smoking-off methods shows a difference in the breaking down of the volatile ingredients of a coal. This discrepancy is least in those coals where there is mechanical loss by the former method. It varies with the complexity of the volatile constituents and is probably due to the variation in the heavy hydrocarbon content, for those coals to which the official method is inapplicable are deficient in illuminants.

(6) If the smoking-off method is employed only when the official method gives inaccurate results, the difference in the breaking down of the volatile constituents is less than that produced by a variation in the amount of water in a coal analyzed by the official method. Under these conditions it will suffice for commercial purposes to neglect the variation in the breaking down of the volatile ingredients by the different heat treatments and to consider the results as directly comparable to those obtained by the official method.

(7) The official method is assumed to approach the conditions existing in a coke oven. In actual practice the coal is charged in large bulk and the distillation necessarily begins slowly. In the smoking-off method furnace conditions are more nearly attained.

THE ACTION OF SODIUM ON ACETONE.

By RAYMOND FOSS BACON and PAUL C. FREER.
(*From the Chemical Laboratory, Bureau of Science.*)

A number of years ago one of us[1] described the action of sodium on acetone, showing that in the presence of absolute ether a *white* sodium derivative is obtained which has 30.17 per cent of sodium (calculated for sodium acetone 28.75 per cent) and which, on being added to dilute hydrochloric acid, regenerates acetone. Subsequently,[2] in a second discussion of the subject it was demonstrated that hydrogen is evolved when sodium acts on acetone, and the resulting sodium derivative is again described as being *white,* but *turning red* rapidly on exposure to air and moisture. It was also shown that when this sodium derivative is added to dilute hydrochloric acid and *repeatedly extracted with ether,* no condensation products of acetone (or at least only traces) could be isolated. The sodium derivative therefore does not contain these condensation produtcs to any great extent. The mother liquors from a number of operations in the preparation of sodium-acetone were carefully retained, united, washed with water, extracted with ether, and the residue distilled, a very small quantity of mesityloxide and some higher condensation products of acetone being isolated. Again, in another discussion of the subject,[3] by acting on sodium under xylene, with acetone, 62.7 per cent of the theoretical amount of hydrogen was obtained (this observation was subsequently confirmed by Beckmann and Schliebs[4]), and in the same paper, in discussing the preparation and analysis of the sodium derivative of acetone, it was shown that delay during the preparation of this derivative always resulted in increasing the percentage of sodium. A large number of samples of acetone-sodium were prepared, decomposed by dilute, ice-cold acetic acid and united until a sufficient amount had been collected to study the reaction products; acetone (isolated as the sodium-bisulphite compound), isopropyl and ethyl alcohols were indentified among these; under favorable circumstances as much as twice the quantity of acetone, as compared with isopropyl alcohol was isolated. The high-boiling fractions from the separation of the above substances gave pinakone, a small quantity of phoron and, presumably, reduction products of the latter. *Mesityloxide could not be isolated.* A portion of the reaction product of sodium on acetone was found to be soluble in ether, this on careful evaporation gave a yellow powder,[5] which oxidized in the air with remarkable readiness. This residue, on acidifying, separates some oil, which was isolated, and the presence of acetone was afterwards proven in the solution. The high-boiling portion of the residue was phoron. These high-boiling oils *react rapidly with phenyl hydrazine.* No isopropyl alcohol and but very little pinakone can be found among the products of decomposition of this soluble portion obtained by the action of sodium on acetone, but by far the greater part of the condensation products produced by the action of sodium on acetone are found in this residue. In proportion as such condensation products are produced, the percentage of sodium in sodium acetone will be increased.

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[1] *Am. Chem. Journ.* (1890), **12,** 355.

[2] Ibid. (1891), **13,** 320.

[3] Ibid. (1893), **15,** 585. *Ann. Chem.* (*Liebig*), **278,** 116.

[4] *Ann. Chem.* (*Liebig*) (1896), **289,** 86.

In a recent number of the Journal of the Chemical Society[6] Millicent Taylor has returned to the subject and comes to the remarkable conclusion that acetone-sodium "consists chiefly of caustic soda mixed with a small proportion of the sodium derivatives of alcoholic reduction and condensation products of acetone."

Apart from the fact that in her discussion Miss Taylor completely ignored the careful description given by one of us of all of the products obtained by the action of sodium on acetone, the statement which she makes that "so-called sodium acetone contains 50.4 per cent of sodium" would in itself be sufficient to cause some doubt as to the accuracy of her results. In our opinion the fact that the product of the action of sodium on acetone, when all acetone and solvent have been removed, on acidifying *regenerates acetone in large amount* is conclusive enough evidence of the existence of sodium acetone, and this fact was repeatedly emphasized in the first series of papers on this subject, but ignored by Miss Taylor in her discussion. Nevertheless, we have deemed it necessary to repeat the work, and here it may be said that at no time, even with the absence of all of the usual precautions, were we able to encounter as much as 50 per cent of sodium in the derivative of the action of sodium on acetone; in ether we obtained 29.2 to 30.9 per cent of sodium and the highest determination (in petroleum ether) gave us 35.5 per cent, these results being in accord with those previously obtained by one of us. In carefully reading Miss Taylor's paper it becomes evident that she always had a *red* substance present after the action of sodium on acetone, both in her experiments on the determination of the amount of sodium in the insoluble precipitate and in the soluble portion. It has in the past been expressly stated that sodium-acetone, when prepared with all precautions, is *white* and that reddening is due to decomposition in the air or by reason if moisture.

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[5] Our work shows that, under proper conditions, this residue is white.

[6] *Journ. Chem. Soc.* (1906), **89**, 1258.

EXPERIMENTAL.

Sodium acetone is a very delicate substance. When properly prepared and when air and moisture are rigidly excluded it is a *snow-white*, flocculent solid. On exposure to the air and to moisture it becomes pink, then red and brown, an oil at the same time separating, the color changes representing the formation of sodium hydroxide and condensation products of acetone. Of course, as had previously been shown, sodium acetone also contains sodium isopropylalcoholate, and some sodium pinakonate and, in the reactions performed under ether, some sodium ethylate. All ether which we used in these experiments was repeatedly dried and distilled from sodium wire until this wire would remain perfectly bright under the solvent. The acetone was from the bisulphite compound and was dried four times over phosphorus pentoxide, each time being poured off and distilled. Dry hydrogen was run through the acetone for some hours to remove any air or carbon dioxide and it was then kept over fused sodium sulphate and protected from moisture and carbon dioxide by tubes containing phosphorus pentoxide and soda lime.

Experiment 1.—The apparatus used was that described by Freer.[7] About 1.6 grams of sodium, cut under coal oil and then washed with absolute ether, were quickly squeezed as a very fine wire into about 50 cubic centimeters of absolute ether in the reaction flask, and the apparatus quickly closed. Dry and pure hydrogen was now run through the apparatus for three hours. The reaction flask was then surrounded by ice and 10 cubic centimeters of acetone, dissolved in 50 cubic centimeters of absolute ether, gradually added through a dropping funnel. Bubbles of hydrogen were given off and the separation of a white, gelatinous precipitate soon commenced. When all of the sodium had disappeared, the ether and precipitate were sucked into a filtering tube, the latter washed eight times with absolute ether, using 50 cubic centimeters each time and always sucking as dry as possible. The precipitate was then dried to constant weight in a current of hydrogen, weighed, and decomposed with dilute, ice-cold sulphuric acid. Only a minimal amount of acetone-condensation products was obtained, as the sodium salt was practically completely soluble in water. In no instance, if the sodium derivative had been properly prepared, was there more than a drop or two of insoluble oil. When small amounts of air or moisture gain access to the sodium derivative, or when the decomposition by acids is not carefully conducted, then these condensation products result, the greater the decomposition, the greater their amount.

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[7] *Am. Chem. Journ.* (1893), **15**, 588.

2.65 grams pure, white sodium acetone were obtained, containing 0.8052 gram sodium.

Required for C_3H_5ONa Sodium.	Found.
Per cent.	Per cent.
28.75	30.3

The acid solution resulting from the decomposition of the product of the action of sodium on acetone was now rendered alkaline with ammonia, and iodine, dissolved in ammonium iodide, added until the color of iodine no longer disappeared. There resulted 6.5 grams of iodoform, equal to 1 gram acetone or 53 per cent of the amount calculated for pure sodium acetone.[8] Undoubtedly, some loss of iodoform occurs in evaporating its etherial solution and all acetone is not converted into iodoform, so that the percentage of acetone is probably really higher than given above.

Experiment 2.—About 1.5 grams sodium wire were dissolved in an excess of acetone diluted with absolute ether, the whole being in an Ehrlenmeyer flask having a very small neck. The flask was not surrounded by ice, the heat generated by the reaction evidently volatilizing enough ether to exclude air, the sodium derivative remaining white. The sodium compound was now rapidly filtered on a Hirsch funnel with strong suction, quickly washed six times with ether and then dried in a vacuum desiccator over sulphuric acid and paraffine. The salt was somewhat pink, but as soon as it was dry it was weighed to a tenth of a gram as quickly as possible and then thrown into ice-cold, dilute acid. The acid was now saturated with potassium carbonate and the low-boiling portion distilled on a water-bath. The distillate was saturated with a solution of sodium bisulphite and the whole cooled in ice for one hour. The acetone sodium-bisulphite (4.5 grams from 3.8 grams sodium compound) was filtered and decomposed with sodium carbonate, the acetone being distilled. There resulted 1 gram of acetone boiling at 54° to 57°.

Experiment 3.—This was carried out exactly as was Experiment 2, with the difference that a sodium determination was made by using an excess of standard acid (found 30.9 per cent). This experiment gave 4.2 grams of iodoform, corresponding to somewhat less than one-half the theoretical yield of acetone for pure sodium acetone.

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[8] We have once more tested this method of determining acetone in the presence of isopropyl or ethyl alcohol, and can substantiate the former statements of Freer that it is sufficiently accurate for the work in hand, the results being *under* rather than over the amount of acetone. Denigés very convenient method of acetone determination is unsuitable as both isopropyl alcohol and mesityloxide give precipitates with his reagent. Denigés, *Compt. rend. Acad. d. sc. Par.* (1898), **127**, 963; *Ann. Chim. Phys.* (1899), VII, **18**, 400; *Bull. d. la Soc. chim.* (1899), III, **21**, 241. Oppenheimer; *Ber. d. chem. Ges.* (1899), **32**, 986; *Chem. Centrbl.* (1899), II, 888.

As will be seen, even in the above two experiments, when air was not rigidly excluded and where the sodium derivative was not handled with particular care, no such high percentage of sodium as that obtained by Miss Taylor, was found. Indeed, in a long series of experiments we have never been able to obtain her results, which could only be accounted for by a profound decomposition of her sodium derivative and the washing out of the acetone condensation products which would be formed. If this decomposition were allowed to go far enough, then practically nothing but sodium hydroxide mixed with the sodium derivatives of alcoholic reduction products would remain.

Experiment 4.—This was performed as was Experiment 1, with the exception that petroleum ether was substituted as a solvent. The reaction in this case is not so clean cut as with ether, the resulting compound is somewhat pink and the sodium percentage higher.

1.745 grams of the sodium derivative gave 0.6203 gram Na and 3.4 grams iodoform, equivalent to 35.5 per cent sodium and 0.52 gram acetone, 41 per cent, respectively.

Experiment 5.—The apparatus was the same as in Experiment 1. 8.515 grams of the sodium compound was obtained, giving 2.567 grams of sodium, equivalent to 30.14 per cent. After the sodium salt had been decomposed, the acid solution was divided into four parts. One of these was saturated with sodium acetate, then made very slightly alkaline and the theoretical quantity of semicarbazid hydrochloride was added. A precipitate of crystalline needles rapidly formed. After the mixture had stood for 12 hours in the ice chest the precipitate was filtered and it gave 1.2 grams of acetone semicarbazone, melting point 186°. This was identical in all respects with a specimen of the same body prepared for comparative purposes. One-eighth of the original acidified solution gave 1.3 grams of iodoform.

Experiment 6.—The conditions were the same as in Experiment 1. 8.25 grams of sodium derivative were obtained, from one-half of this, acidified, etc., 2.9 grams acetone semicarbazone, melting at 186°, were separated, and from one-quarter, 2.2 grams iodoform were precipitated. One other sodium determination gave us 29.2 per cent of sodium.

The above experiments render it practically certain that a sodium derivative of acetone exists among the products of the action of sodium on acetone, as acetone is obtained by their decomposition with acids. However, it might possibly be true that the reaction product is sodium isopropylate together with some caustic soda and that the acetone which is found is held by the sodium isopropylate in a combination somewhat similar to alcohol of crystallization. That this is unlikely is proved by the fact that the sodium derivative formed by the action of sodium on acetone, after filtering and washing, was dried *in vacuo* to constant weight, while at the same time it was *warmed* to beginning decomposition. If acetone were present in a condition such as the above, it certainly would be driven off by this treatment; nevertheless, the sodium derivative behaved as usual when it was added to dilute acid. That sodium isopropylate does not behave as does sodium acetone even when it is mixed with acetone is shown by the next experiment.

Experiment 7.—2.5 grams of sodium were dissolved in an excess of isopropyl alcohol and diluted with absolute ether. The white color did not change in the least when the derivative was allowed to stand for three hours in an open beaker, whereas the product of the action of sodium on acetone, placed beside it under the same conditions, decomposed and completely changed in five minutes. When acetone was added to sodium isopropylate under ether, the resulting mixture remained unchanged for a long time when exposed to the air, although after one hour it had assumed a slightly pink tinge. It was now filtered, washed three times with absolute ether, dried and thrown into dilute sulphuric acid. The usual acetone test gave no trace of iodoform. Acetone is therefore not retained by sodium isopropylate.

Miss Taylor suggests that the reaction first observed by one of us may be due to the formation of the sodium salt of diacetone alcohol $(CH_3)_2.COH.CH_2.CO.CH_3$. This compound is formed from acetone in the cold under the influence of hydroxyl ions. Koelichen[9] has shown that in the presence of hydroxyl ions there is an equilibrium between the amounts of acetone and of diacetone alcohol, thus with a concentration of hydroxyl ions represented by a 10 per cent solution of sodium hydroxide, the quantity of diacetone alcohol is 3 per cent of the total acetone, and smaller in quantity for a lower concentration of the ions. The sodium compound of this body would contain 14.37 per cent of sodium. We have prepared diacetone alcohol according to the method of Koelichen and subjected it to the action of sodium. The alcohol was diluted with absolute ether and in an open beaker dissolved sodium very rapidly, with marked reddening of the resulting compound, the action resembling closely that observed when acetone is similarly treated in the open air, but on acidifying the product, mesityl oxide and other condensation products of acetone are separated and acetone could be demonstrated in the solution by the formation of its semicarbazone, melting at 185° to 186°.

A different result is obtained in an atmosphere of dry hydrogen. In the apparatus used in Experiment 1, and under absolute ether, diacetone alcohol is only very slowly attacked by sodium, giving a yellowish sodium derivative. Over four hours were consumed in dissolving 0.5 gram of sodium in 5.5 grams of the alcohol. The precipitate was filtered, dried in a current of hydrogen and dissolved in dilute acid, a considerable quantity of condensation products of acetone separating. 0.74 gram of the sodium derivative gave 1.067 grams sodium sulphate or 46.8 per cent sodium. It seems evident, therefore, that sodium acting on diacetone alcohol really does give sodium hydroxide and the condensation products of acetone; the reaction is, however, so radically different from the action of sodium on acetone, and the condensation products so prominent (there are scarcely any when pure sodium acetone is dissolved in dilute acids) that the theory that diacetone alcohol is first formed, subsequently to be acted on by sodium, must be abandoned. There remains only the question then of whether sodium acetone could not react with acetone to give the sodium derivative of diacetone alcohol, although in this event the percentage of sodium found should be very much less than it really is. However, apart from this, in the absence of condensation products of acetone on acidifying, it must be presumed, to account for the acetone which is always found in the acidified solutions of sodium acetone, that the diacetone alcohol would promptly be reconverted into acetone during this process. Rigidly to exclude this supposition we performed the following experiment.

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[9] Koelichen: *Ztschr. f. physikal. Chem.* (1900), **33**, 129. Heintz: *Ann. Chem.* (*Liebig*) (1873), **169**, 114.

Experiment 8.—Four grams of diacetone alcohol were dissolved in 20 cubic centimeters of ethyl alcohol and 20 cubic centimeters of water. The solution was saturated with sodium acetate and 4 grams of semicarbazid hydrochloride were added. The solution was then rendered very faintly alkaline and placed in ice-water for one hour, being vigorously scratched with a glass rod. No precipitate appeared. To be sure that the conditions were correct for the formation of a semicarbazone, the solution was divided into two equal portions. To portion number two, 2 grams of acetone were added, whereupon a precipitate of crystalline needles immediately appeared. Four grams of semicarbazid hydrochloride were now added to this portion of the original solution, so that a sufficiency of the reagent should be present to precipitate all acetone and all diacetone alcohol, should it form a semicarbazone. Both the original, unchanged portion and the second one were kept in the ice chest over night. In the morning, portion number one, to which no acetone had been added, contained a very faint precipitate (0.01 gram melting at 185° to 186°, it being acetone semicarbazone) so that a very small amount of acetone had been separated by hydrolysis. From portion number two, 2.5 grams of acetone semicarbazone were isolated, melting at 186°.

From the above result it is evident that the acetone semicarbazone obtained in the preceding experiments could not have originated in the sodium derivative of diacetone alcohol as the hydrolysis of the latter body is a time reaction which proceeds slowly.

The above results confirm the previous work in every way and establish the fact that the action of sodium on acetone gives a sodium derivative which can only be sodium acetone.

In view of the above conclusions it is not deemed necessary further to discuss Miss Taylor's results as, apparently, she had not reproduced the conditions under which Freer worked. A very short review of some of the chief facts established in the earlier literature and which Miss Taylor appears not to have considered may not be out of place, as it will serve to recall some of the arguments which were not discussed in Miss Taylor's paper. The portion of the product of the action of sodium on acetone which is insoluble in ether was shown by Freer[10] to consist of acetone sodium, sodium isopropylate, and disodium pinakonate, the soluble portion, of a sodium derivative of acetone, no sodium isopropylate was isolated from this soluble portion and, if it is not carefully acidified, mesityloxide and phoron are to be obtained. In studying the products of the action of chlorcarbonic ether on sodium acetone, Miss Taylor suggests that a mixture of ethyl isopropyl carbonate and diethylcarbonate would yield 34 per cent of carbon dioxide, whereas Freer found 33.89 per cent on decomposing the oil boiling between 128° and 129° and produced by the interaction of sodium acetone and chlorcarbonic ether (calculated CO_2 for $C_6H_{10}O_3$, 33.84 per cent), but Miss Taylor appears to have overlooked the statement[11] that Freer also proved the presence of ethyl alcohol and *acetone* in the products left after saponification. If acetone had been present as mesityl-oxide, the percentage of carbon dioxide would have fallen very much. It was further shown by Freer that the fraction boiling at 128°[12] yielded a sufficient amount of acetone on decomposition with dilute acid to allow of its being separated as the acetone sodium-bisulphite compound. (Found carbon dioxide 33.7 per cent; the quantity of ethyl alcohol was less than one-half the organic liquid isolated, it boiled at 78°.) We would, therefore, if we were dealing with a mixture of diethylcarbonate, ethyl isopropyl carbonate and mesityloxide, need to assume a large proportion of the latter substance to be present, and this would inevitably have lowered the carbon dioxide very markedly. Furthermore, the oil boiling between 132° and 137° yielded 30 per cent of *acetone* (calculated, 48.8 per cent) and this figure, because of the difficulties in quantitative estimation, is undoubtedly too low. It does not seem reasonable to assume that an oil which would contain a sufficient quantity of mesityloxide to yield so much acetone would not further react with phenylhydrazine, but on the other hand this percentage would correspond to a total of 62 per cent of the isoacetone ester in the oil. Miss Taylor's supposition is that this acetone comes from mesityloxide present in the mixture. If enough mesityloxide occurred in the mixture to yield 30 per cent of acetone, then the carbon dioxide found would be reduced by 11 per cent, to say nothing of the change brought about in the analytical results. A mixture which consists of ethyl isopropylcarbonate, diethylcarbonate and sufficient mesityloxide to yield 30 per cent of acetone and which will also give 33.7 per cent of carbon dioxide, can not be calculated. Miss Taylor allowed her reaction product to stand over phenylhydrazine for four days. It is possible that, if isopropenylethylcarbonate was present at all, it would by that time have reacted with phenylhydrazine; it is also possible that, owing to some variation in her work Miss Taylor never had the body in the oil she prepared. Attention is further called to the fact that Freer obtained enough 2-chlorpropene by the action of phosphorus pentachloride to isolate this very low-boiling substance. The reaction product also absorbs bromine in the cold, without yielding hydrobromic acid.

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[10] *Amer. Chem. Journ.* (1893), **15**, 592.

[11] *Ibid.* (1891), **13**, 325.

[12] *Ibid.* (1895), **17**, 11.

Miss Taylor did not use benzoyl chloride in studying the composition of sodium acetone, substituting p-nitrobenzoyl chloride therefor. Again, in her reaction she does not seem to have had a sodium derivative which acted like the one described above, for she obtained *none of the addition* products described by Freer as a result of the action of benzoyl chloride on sodium acetone. That p-nitrobenzoyl chloride might not form an isoacetone ester is conceivable, but in that event it *should* give addition products. Freer, in studying the action of benzoyl chloride on sodium acetone separated the reaction products into two parts, one soluble in alkalies, the other insoluble. In this instance, the insoluble oil (12 grams) boiling at 120° (39 millimeters pressure) added bromine in the cold, gave acetone in sufficient quantity to be isolated from the sodium-bisulphite compound, isopropyl alcohol, and ethyl alcohol. The organic liquid containing the acetone was twice as great in volume as the remainder. The portion of the reaction product which was soluble in alkalies yielded acetophenon, *mono-* and *dibenzoyl* acetone. Here we are not dealing with a mixture of oils, but with crystalline solids which can be isolated in the pure state. It is difficult to see how mono- and dibenzoyl acetone could result from a mixture of condensation products of acetone, sodium isopropylate and caustic soda. Sodium acetone must have taken part in the reaction.

It should also be remembered that Freer and Lachman [13] studied the action of sodium on methyl propylketone, obtained 22.1 per cent of sodium in the derivative (calculated 21.3 per cent), isolated dibenzoyl methyl propylketone, and from 2 grams of the alkali insoluble portion obtained 0.9 gram benzoic acid, 1 gram methylpropylketone, some halogenated oil, and some hydrochloric acid. The entire 2 grams is therefore accounted for. Intermediate halogenated addition products were also demostrated.

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[13] *Amer. Chem. Journ.* (1897), **19**, 878.

Pure mesityloxide reacts so energetically with sodium that the products may even take fire with explosive violence, the sodium compound is so unstable that it can not be isolated.

From the above considerations it is evident that the original descriptions of sodium acetone remain unaltered.[14]

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[14] Since the above was written an article by Levi and Voghera (Gazz. chim. Ital. (1905), **35**, I, 277) has come to our attention. These investigators studied the electrolysis of KSCN, KI and NaI in acetone solution, water being rigidly excluded from their solutions. At the cathode sodium-acetone respectively potassium-acetone separated as white substances. With water these gave acetone and sodium or potassium hydroxides. The potassium-acetone gave 40.70 per cent of potassium (calculated 40.62 per cent), and it dissociated, when placed in water, into acetone, potassium and hydroxyl ions, the correct lowering of the freezing point for a molecular weight of 96 was obtained (found 95.3).

A NEW SUBSPECIES OF PHILIPPINE CICINDELIDÆ.

By Walther Horn.

(*Berlin, Germany.*)

Family **CICINDELIDÆ.**

CICINDELA.

Cicindela clara Schaum, rugothoracica, subsp. nov.

Differt a *Cic. clara suavissima* Schaum, fronte antica et vertice paullo, pronoto multo grossius rugatulis (his rugis plus minusve transversis); pronoto subopaco, multo minus convexo, disco ipso paullulum deplanato, antice magis dilatato; elytris evidenter minus gibbosis, postice minus declivibus neque micantibus; signatura testacea (♀ macula apicali suturali albescente): maculis omnibus minoribus, puncto subhumerali magis a margine distante. Corpore supra viridi (♀ capite prothoraceque plus minusve violaceo-aeneis, elytris nigroviolaceis), subtus (et 4 primis antennarum articulis) coeruleo-viridi, episternis ♀ purpureo-violaceis. Long, 7.5–8 mm.

Differt a subspecie *aenula* mihi vertice prothoraceque evidenter crassioribus, fronte antica et vertice et pronoto grossius rugatis; hoc antice magis dilatato, disco minus convexo, basim versus non declivi sed sat gradatim descendente; puncto subhumerali magis a margine remoto, elytris aut nigro-violaceis aut viridibus, episternis aut clarius purpureo-violaceis aut viridibus.

1♂1♀, Ins. Philipp. (Coll. R. C. McGregor) Benguet, Irisan.

Specimen alterum in coll. Bureau of Science, Manila, P. I., alterum in mea.

Type ♀, No. 1515 in Entomological Collection, Bureau of Science, Manila.

The pronotum bare, with only a few white bristles at the anterior and posterior angles. Lateral portions of the under side of the body sparingly pilose, disc of the abdomen bare. Trochanters brownish, maxillary palpi dark-metallic. The coloration of the body and that of the pattern may be individual.

The new species resembles, in some features, *Cic. suavis* m., but the latter has the disc of the abdomen pilose, the lateral portions of the under side and the whole lateral margin of the pronotum denser pilose, head and pronotum finer sculptured (especially the wrinkles near the eyes much finer), the transverse impressions and strangulations of the pronotum less deep, the last one less dilated at the front; elytra longer, more nearly parallel and (especially behind) flatter, the spot below the shoulder just a little nearer the border; maxillary palpi and base of femora pale-yellow.

REVIEWS.

Surveying and Levelling Instruments Theoretically and Practically Described: for Construction, Qualities, Selection, Preservation, Adjustments, and Uses; with Other Apparatus and Appliances Used by Civil Engineers and Surveyors in the Field. By William Ford Stanley. Cloth; 372 illustrations in the text. Pp. xv+562. Price, 7s. 6d. London: E. & F. N. Spon. 1901.

This is perhaps the only book in the English language, with the exception of surveying text-books and trade catalogues, which treats of the manufacture, use, and adjustment of mathematical instruments. For the purposes for which it is intended it is more valuable than either of the above classes, being far more comprehensive than text-books and more impartial than catalogues.

With an experience of about fifty years in the manufacture of scientific instruments, the author must certainly be well qualified to treat of his subject, both from the practical and the theoretical standpoint, but in regard to its impartiality, the book is perhaps open to criticism. It is not surprising when we consider that all engineers have habits of their own, that the author should have his own prejudices, and quite natural that they should be favorable to instruments of his own manufacture. It is not intended to convey the impression that the book is merely an elaborate exposition of the author's manufactures, a sort of catalogue in text-book form. It is far more than that, for other systems and other makes are frequently mentioned and compared; simply, that the author dwells longest on his own and does not devote as much space to other instruments, with which the American engineer at least, is more familiar. Yet, if this is a fault, it must be considered a pardonable one, for it would be plainly impracticable to describe in detail all the different kinds of surveying instruments which are in use in different countries, so if the author must choose, he selects those with which he is most familiar.

The book is of value not only to those interested in the manufacture of surveying instruments, but especially to men in the field who in emergencies may be compelled to make their own repairs. It contains much useful information and many practical hints on the preservation, testing and repair of instruments which can be found in no other book. Older men as well as the less experienced will therefore find it useful for reference.

M. G.

Mathematical Drawing and Measuring Instruments. Their Construction, Uses, Qualities, Selection, Preservation, and Suggestions for Improvements; with Hints upon Drawing, Colouring, Calculating Sun Printing, Lettering, etc. By William Ford Stanley. Seventh edition. Cloth; 247 illustrations in the text. Pp. vii+370. Price, 5s. London: E. & F. N. Spon. 1900.

On the subject of impartiality, this book is open to criticism. For instance, an entire chapter is given up to various improvements and modifications of the pantagraph manufactured by the author, while the suspended pantagraph, which is an improved form very commonly used in America, is not even mentioned. Thus also, the ordinary triangular scale receives a brief mention to the effect that it is not much used and not much recommended. The patented triangular scale, in which the graduations are raised from the drawing surface, is not mentioned, although it has been one of the most commonly used drafting instruments in America for more than ten years. While the book may properly be described as a desirable reference book for the draftsman, we would by no means classify it as an essential. The majority of the instruments described are those with which every draftsman is, or at least should be, perfectly familiar, while the others such as oögraphs, cymagraphs, and odontographs, the descriptions of which occupy a good portion of the book, are instruments which probably not one draftsman in fifty will ever see or ever possess. While these, which may be called special instruments, have their peculiar uses, the work of most of them can usually be performed, perhaps less conveniently, by other simpler and more generally useful appliances. In large establishments such instruments may occasionally be the most economical and desirable, and the draftsman should, therefore, at least be aware of their existence. This purpose the book serves admirably, not only describing them in considerable detail but also telling the particular work for which each is best adapted.

M. G.

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PHILIPPINE FIBERS AND FIBROUS SUBSTANCES: THEIR SUITABILITY FOR PAPER MAKING. PART III (CONCLUSION).

By GEORGE F. RICHMOND.

(*From the Chemical Laboratory, Bureau of Science, Manila, P. I.*)

INTRODUCTION.

The gradual but certain decrease in the available supply of the leading paper makers' raw material at the present time is further emphasized, by recent compilations concerning the American pulp wood industry. Some of the more important considerations brought out in a circular report on wood used for pulp[1] in 1905 are:

First. The increase in the quantity consumed, 3,192,223 cords being used during 1905, or a gain of 60.7 per cent over the corresponding figures for 1899.

Second. The increased use of chemical processes for the reduction of wood to paper pulp. In 1905 the proportions were approximately 66 per cent of chemical and 34 per cent of mechanical pulp; these percentages representing a gain of 74.7 per cent for the chemical process as against one of 39.4 per cent for the mechanical during six years.

Third. The greatly increased use of woods other than spruce and poplar, and a more general utilization of waste products from lumbering industries. Such wood species as hemlock, fir, southern, pitch and jack pines and even the hardwoods such as beach and maple, are now being employed, while slabs, sawdust and veneer cores are also being considered.

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[1] Hale, H. M.: *U. S. Dept. Agriculture, Forest Service Circ.* (1906), No. 44.

Fourth. An increase of approximately 75 per cent is also shown in the amount of pulp wood imported. This importation consists of 645,428 cords of Canadian spruce and poplar.

Fifth. The estimated length of time during which the supply will be available is given as twenty-one years.

The United States Forest Service has established a laboratory at Boston, Massachusetts, for a further investigation of the woods mentioned above as well as of other varieties and also of the waste materials, and the following quotation serves to explain the reason for its existence.

> To supply the enormous demand for the sulphite product more than 1,500,000 cords of wood are used annually. Nearly four-fifths of this amount is spruce. A rapid diminution in the supply of standing spruce and a consequent marked increase in its cost are the results of this great and growing demand. Therefore, the principal object of the laboratory is to experiment on the pulp-making possibilities of other woods.[2]

The experiments to be conducted in the Boston laboratory are intended to include the investigation of a large number of American woods and waste products; their applicability to the sulphite process of treatment; a microscopic study of the fibers and the distribution of samples of pulp and handmade sheets of paper made therefrom.

Generally speaking, the species of woods best suited for paper pulp should possess the following characteristics:

First. They should be soft, but of a resistant nature, and they should possess long, fine, parallel fibers.

Second. They should be light in weight and colorless or nearly so. The species which have the distinct heart- and sap-wood may be employed, if the distinction is not too pronounced.

Third. They should be but moderately resinous with a comparatively thin bark, and they should be relatively free from knots and unsound portions.

The above requirements seem to be met by a sufficient number of Philippine forest trees to warrant a study of their pulpmaking possibilities. Authentically identified specimens of the different woods, together with data as to their distribution, description and physical properties, were furnished by Dr. H. N. Whitford of the Philippine Bureau of Forestry and by Dr. Foxworthy of the botanical section of the Biological Laboratory, and the botanical identifications were made by Elmer D. Merrill, botanist of the Bureau of Science.

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[2] *Forestry and Irrigation*, Wash. (1906), **12**, 8.

TABLE No. 1.—*Tree species proposed.*

Botanical name.	Common name.	Specific gravity.	Weight per cubic foot.	Ash.	Remarks.
			Kilos.[a]	*Per cent.*	
Shorea contorta	White lauan	0.446	12.56	0.89	Moderately resinous.
Parkia roxburghii	Cupang	.285	8.03	2.08	Non-resinous.
Anisoptera vidaliana	Mayapis	399	11.24	.83	Do.
Alstonia scholaris	Dita		12.72	.99	Do.
Sandoricum vidalianum	Santol		16.36	1.12	Do.

[a] 1 kilo = 2.2 pounds.

PHILIPPINE WOODS.

LAUAN (*Shorea* sp.).

Structural qualities.—Lauan is a light and soft wood which takes a fair polish; the pith rays are fine but distinct, in radial section they are very prominent as horizontal lines or patches of a darker color than that of the surrounding wood; this dark color is due to resin contained in the pith-ray cells. The vessels are of medium size, often filled with gummy material; wood parenchyma is present, but of irregular distribution. The resin canals are small and scattered, often forming distinct, white, concrete lines.

Appearance, color and grain.—Both heart-wood and sap-wood of lauan are of a light-brown to whitish shade. The wood is straight, but of rather coarse grain.

Uses.—Lauan wood is employed in light and temporary construction. It is also used in cabinet making, in inferior furniture, and for small boats.

Provinces leading in production.—Negros Occidental, Bulacan, Bataan, Leyte and Zambales.

Remarks.—This is the most widely distributed tree in the Philippine forests. It is found in limited numbers in every type of lowland forest excepting the swamps, and it is also present in the foothills. Lauan has a tall and regular bole. The young trees are but slightly buttressed, but the old ones often show this development to a great degree. Several different kinds of wood are marketed under the name of lauan, the classification being as red and white. The red lauans are undoubtedly distinct in species from the true white lauan (*Shorea contorta* Vid.). There are at least two white lauans found in the Provinces of Mindoro, Bataan and Zambales, and another species (*Shorea squamata* F.-Vill.) is obtained from Negros, this variety is also locally known as *almon.* The tree designated as *malaanonang* (*Shorea malaanonan* Blume) and found scattered through the forests of Rizal and Bulacan Provinces also greatly resembles the poorer grades of lauan both in appearance and structure. It is much lighter in color than any of the commercial red lauans, and from its structure it should be considered as being useful for fiber production in the same manner as is the true white lauan.

CUPANG (*Parkia roxburghii* Don.).

Cupang is a light and soft wood. It is not durable and rots quickly; there is no distinction between sap- and heart-wood; its color is white or whitish. It is coarse grained, splitting more or less regularly; its odor is pronouncedly mephitic when it is fresh or when it is partially rotted, it is less pronounced when the wood is dry.

The vessels are of medium size, each surrounded by a collar of whitish cells; the pith rays are small but distinct, they are lighter in color than the surrounding tissue.

Distribution.—Cupang is probably found in lowland forests in every province of the Archipelago; it also occurs in India and throughout Malaysia.

Uses.—Cupang has no commercial use at the present time. It was formerly employed in the manufacture of matches, but its use was discontinued because of its odor.

Remarks.—Both *lauan* and *cupang* are free from knots from base to crown. Cupang grows to large diameter, with a smooth, straight cylindrical bole, which is often quite short. Usually a clear length of 40 to 55 feet terminates in a much branched crown.

MAYAPIS (*Anisoptera* sp.).

Structural qualities.—Mayapis is a light, soft wood and is not durable. In structure it very much resembles lauan, however it is distinctly coarser grained. Its vessels are slightly larger and more numerous and its pith rays are rather more distinct.

Appearance, color and grain.—Mayapis is yellowish-white in color and coarse grained.

Uses.—It is used in light and temporary construction.

Provinces leading in production.—Laguna, Tayabas, Bataan and Cagayan.

Common names.—Mayapis, palosapis, etc.

Remarks.—The tree which yields most of the lumber known as mayapis is probably *Anisoptera vidaliana* Brandis, although some other closely related species may also be known as mayapis or palosapis. This tree has a long, straight, clean bole with a small taper, the clear lengths varying from 50 to 80 feet. Its average diameter is about 20 inches.

DITA (*Alstonia scholaris* R. Br.).

Dita is a light and soft wood weighing 28 pounds per cubic foot; it seasons badly and it rapidly becomes moldy if seasoned in the log.

Appearance, color and grain.—There is no distinction between sap- and heart-wood; it has a white, even grain which is fine and straight. The pores are medium sized; the pith rays fine and irregularly distributed, with numerous intermediate extremely fine rays; there are many fine, wavy concentric lines at unequal distances. The wood has a very bitter taste; it is easy to work and is used for light furniture of various sorts and for the manufacture of matches.

Alstonia scholaris is a very large, evergreen tree, with smooth bark and straight clear bole. It is found in old clearings.

Distribution.—Dita is widely distributed throughout the Archipelago and also extends from India to the Philippines.

Remarks.—Dita is furnished by *Alstonia scholaris* R. Br. and by no other species.

SANTOL (*Sandoricum* sp.).

A moderately hard and heavy wood, weighing 16.4 kilos (36 pounds) per cubic foot. The sap-wood is gray, the heart-wood faintly reddish, resembling the color of hemlock. It is close and straight grained, very easy to work and it takes a fine polish. The wood has a camphor-like odor when first cut. The pores are small and the medullary rays fine.

Distribution.—The tree is very common in cultivation and in old clearings, also in lowland forests; it is found throughout the Philippines and in the Indo-Malayan region.

Remarks.—The scientific designation is *Sandoricum indicum* Cav., but the very similar wood *malasantol* is common in the forest and is furnished by the closely related *Sandoricum vidalii* Merr.

Other woods worthy of mention, but upon which no work has been done are *taluto* (*Pterocymbium tinctorium* Merr.), *malapapaya* (*Polyscias nodosa* Seem.), *papaya* and *balete* and other species of the genus *Ficus, Grewia* sp., etc. All of these are of common occurrence, are very soft and light and are white or nearly so in color. They all mold very quickly if allowed to cure in the log.

DATA ON THE STAND OF CUPANG, LAUAN AND MAYAPIS IN BATAAN PROVINCE.[3]

On the west coast, the basin drained by the Binonangan River comprises approximately 6,120 acres. The topography of this area is such that lumbering operations can easily be carried on. The distance from the coast to the most remote timber in this basin is about 6 miles. The area is well forested, except for a narrow strip on the seacoast where the timber is small and scattered. The principal wood species found on this area are panao, tanguile, lauan, guijo, mayapis and cupang. The cupang, among the pulp woods, covers only the lower elevations up to 900 feet, an area of approximately 3,900 acres, while the lauan and mayapis are distributed over the whole region.

The estimated total stand of the three woods is given as—

	Cubic feet.
Cupang	1,870,720
Lauan	1,578,960
Mayapis	1,040,400
Total	4,490,080

These figures represent only the merchantable stand in the basin, of trees of these species of 20 inches or more in diameter after making an average deduction of 20 per cent for unsound timber; hence 5,000,000 cubic feet of pulp wood may be obtained from this small area.

The yield tables[4] for the merchantable stand of timber on 4,590 hectares (11,339 acres) of public forest on the eastern coast of Mindoro show a yield of 14,060,778 cubic feet, cutting to a diameter limit of 40 centimeters (16 inches); of this amount 6,453,368 cubic feet is white lauan.

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[3] Bryant, R. C.: *Rep. Bu. Forestry*, P. I., (1901–1902).

[4] Merrit, M. L., and Whitford, H. N.: *Phil. Bu. Forestry* (1906); **6.**

THE SHRINKING OF THE VARIOUS WOODS ON BARKING.

Experiments to determine the shrinkage of the various woods in barking gave the following results:

TABLE No. 2.—*Green wood containing 30 to 40 per cent of moisture—blocks one-foot in length varying 15 to 20 centimeters in diameter.*

Kind of wood.	Weight.		Loss.
	Before barking.	After barking.	
	Kilos.	*Kilos.*	*Per cent.*
Lauan	2.695	2.443	9.3
Cupang	5.430	4.800	11.6
Mayapis	7.587	6.740	11.00
Dita	8.061	6.670	17.25
Santol	8.969	8.012	10.67

One cord of green spruce, containing 37 per cent of moisture and cut in 4-foot lengths, weighed 2,001 kilos (4,440 pounds); after barking it was 1,622 kilos (3,570 pounds) or 19.5 per cent shrinkage.[5]

TABLE No. 3.—*Dimensions of the ultimate fibers of some Philippine woods.*

[Table by Dr. Foxworthy.]

Name.	Length.			Diameter.					
				Total.			Lumen.		
	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Lauan (Shorea contorta)	2.28	1.94	1.13	0.026	0.022	0.017	0.017	0.014	0.009
Mayapis (Anisoptera vidaliana)	2.62	1.92	1.16	.030	.023	.019	.0092	.0058	.0031
Cupang (Parkia roxburgii)	1.80	1.15	.86	.038	.029	.021	.026	.020	.014
Dita (Alstonia scholaris)	1.85	1.27	.80	.041	.0355	.025	.025	.016	.010
Spruce[6]	4.54	3.15	1.67	.043	.037	.034	.029	.0195	.003

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[5] Griffin and Little: Chem. Paper Making (1894), 141.

[6] Sulphite pulp manufactured by Willamette Pulp and Paper Company, Oregon City, Oregon.

TABLE NO. 4.—*Proximate analyses of Philippine woods and some commercial pulp woods.*

Kind of wood.	Water.	Aqueous extract.	Alcohol ether extract.	Cellulose.	Incrusting matter.	Ash.
PHILIPPINE WOODS.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Lauan	11.23	3.85	2.72	61.71	19.57	0.89
Mayapis	11.50	4.50	1.20	55.73	28.24	.83
Cupang	13.33	3.45	1.17	60.56	19.41	2.03
Dita	10.41	4.19	.60	49.94	33.87	.99
SOME COMMERCIAL PULP WOODS.[7]						
Scotch pine	12.87	4.05	1.63	53.27	28.18	----------
Block poplar	12.10	2.88	1.37	62.77	20.88	----------
Silver fir	13.87	1.26	.97	56.99	26.91	----------
Bass-wood	10.10	3.56	3.93	53.09	29.82	----------
Spruce[8]	11.31	4.83	3.28	52.96	35.41	0.32
	11.48			53.08	35.19	.25
	11.26			52.98	35.46	.30

SODA WOOD PULPS.

One-kilo lots (2.2 pounds) of wood were barked, chipped and cooked in the model digestor, washed, screened and molded into 7 by 10 inch boards. These were first air-dried and weighed, then repulped and beaten in a small hollander, bleached and formed into unsized handmade sheets.

TABLE NO. 5.—*Experiments with lauan.*

Experiment No.	Caustic soda solution.	Caustic soda calculated on weight of material.	Duration of digestion.	Pressures carried.	Yield of pulp.		Bleaching powder consumed.	Loss of weight in bleaching.
					Unbleached.	Bleached.		
	Per cent.	*Per cent.*	*Hours.*	*Atmospheres.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10	25	9	6	40.9	----------	----------	----------
2	7.5	22.5	11	6	42.37	40	17.1	5.69
3	5	20	5	5 (7½)	45.2	40.3	18.8	10.8
4	3.75	15	10	6–8	45.28	----------	----------	----------
5	3.5	12.5	10	6–8	48.6	----------	----------	----------

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[7] Müller, Hugo: Die Pflanzenfaser, Leipz. (1873), 150.

[8] Analyses by Griffin and Little.

Remarks.—The conditions of experiment 3, namely, a 5 per cent (6° to 7° Baumé) liquor and five hours' digestion at 7 to 8 atmospheres' (105 to 120 pounds) pressure produced a well-boiled pulp, comparatively free from screenings. In experiment 4, a weaker liquor accomplished the same result in double the time, at a slightly increased pressure. Experiment 5 produced a coarse pulp, very brown and badly contaminated with shive. Experiment 1 showed evidence of too caustic a treatment.

TABLE No. 6.—*Experiments with cupang.*

Experiment No.	Caustic soda solution.	Caustic soda calculated on weight of material.	Duration of digestion.	Pressures carried.	Yield of pulp.		Bleaching powder consumed.	Loss of weight in bleaching.
					Unbleached.	Bleached.		
	Per cent.	*Per cent.*	*Hours.*	*Atmospheres.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	7.5	25	8	7	41.91	----------	----------	----------
2	6	20	10	6	43.71	40.3	16.5	7.8
3	4.7	20	8	7	44.97	40.2	18.4	10.6
4	3.75	15	8	6–8	48.4	----------	----------	----------
5	3.5	12.5	8	6–8	50.4	----------	----------	----------

Remarks.—Under similar conditions of treatment, cupang pulps more easily than lauan and with a little better yield. The pulp resembles poplar, in length of fiber and ease of treatment although it is somewhat harder to bleach.

TABLE No. 7.—*Experiments with mayapis.*

Experiment No.	Caustic soda solution.	Caustic soda calculated on weight of material.	Duration of digestion.	Pressures carried.	Yield of pulp.		Bleaching powder consumed.	Loss of weight in bleaching.
					Unbleached.	Bleached.		
	Per cent.	*Per cent.*	*Hours.*	*Atmospheres.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	10	22	5–6	5	38.5	----------	----------	----------
2[a]	6.25	20	10	6–7	41.85	40.7	9.9	2.74
3[b]	5	20	5	6–7	42.5	41	12	3.53
4	4	17.5	5	6–7	44	41.19	15.4	2.81

[a] Good white color. [b] Yellowish color.

Remarks.—Mayapis is one of the most promosing of the Philippine pulp woods. It is even lighter in color than white lauan and has a considerably longer fiber than cupang. A yield of 40 to 45 per cent of easily bleached pulp may be expected by digestion with alkaline liquors.

Dita wood is too short fibered and weak to be of much value for paper pulp. It is briefly considered here because of its wide distribution and abundance in the Philippines and because it would yield the bark which contains the most widely known and important Filipino drug as a by-product. The alkaloids from dita bark are being investigated by Dr. R. F. Bacon of this Bureau.[9]

Only two soda digestions on dita wood were made. The wood is very easily reduced, but its yields are 5 to 10 per cent lower than those of the others under identical conditions of treatment.

Experiment 1.—Strength of liquor, 4.4 per cent; 20 per cent caustic soda used calculated on the air-dried weight of the wood; pressure, 5 to 6 atmospheres; time, 8 hours; yield, 35 per cent.

Experiment 2.—Strength of liquor, 3.3 per cent; 15 per cent caustic soda used calculated on the weight of the wood; pressure, 5 to 6 atmospheres; time, 8 hours; yield, 38 per cent.

SULPHITE WOOD PULP.

I have conducted a large number of sulphite digestions on selected species of Philippine woods, under varying conditions of strength of liquor, duration of boiling, temperature and pressure. An upright, steel digester capable of holding several pounds of raw material was constructed for these experiments. The conditions obtained in practice were thus closely approximated and they furnish reliable data which can readily be calculated in terms of ton lots of raw materials and of chemicals.

Considerable difficulty was encountered in constructing a gas-tight digester and in protecting the iron shell from the corrosive action of sulphite liquors. After failing in several attempts to make sheet-lead or silicate-paint linings which would hold, the following arrangement suggested by the Director was adopted throughout all the sulphite experiments.

A large stoneware chemical jar with ground stone cap and spring clip seal was placed inside the steel digester shell and surrounded with water containing sufficient alkaline bicarbonate to equalize the pressure produced by the free sulphurous acid gas on the inside of the jar. A drop tube carrying a thermometer and dipping into the outside liquor between the stone and iron walls allowed of perfect registration of the temperature conditions of the digestions.

In a small way, we were able to deposit a very smooth adherent lead lining on iron by the Bett's[10] process for refining base bullion in fluosilicic acid solution, but the proper current density and other conditions were not at hand for lining our large digester in this manner.

The woods were barked and chipped in the usual manner and cooked by the quick-cook system, namely at high temperatures for a relatively short time.

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[9] *This Journal* (1906), 1, 1007.

[10] *Electro Chem. and Metallurgical Ind.* (1905) 3, 272.

TABLE No. 8.—*Sulphite digestions on Philippine woods* (*quick-cooking process*).

Kind of wood and experiment No.	Composition of liquor.			Duration of digestion.		Maximum temperature carried.	Yield of pulp.		Bleaching powder consumed.	Screenings.
	Total SO_2.	Combined SO_2.	Available SO_2.	Time to reach maximum temperature.	Total time.		Unbleached.	Bleached.		
Lauan:	*Per cent.*	*Per cent.*	*Per cent.*	*Hours.*	*Hours.*	°*C.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	3.6	1.6	2.0	4	12	160	42.2	----------	--------	1.8
2	3.5	1.2	2.3	5½	11	150	44.4	43.3	13.4	--------
3	3.75	1.78	1.97	4½	11	155	46	----------	--------	1.75
Mayapis:										
1	3.52	1.63	1.89	4½	9	151	47.27	----------	--------	--------
2	3.45	1.35	2.10	5½	11	150	44.75	42.35	14	--------
3	3.75	1.78	1.97	4½	11	155	46	----------	--------	1.4
Cupang:										
1	3.6	1.2	2.4	4	10	145–155	46.76	43.02	8.51	--------
2	3	-------	-------	4	16	160	49.4	----------	--------	3.0
3	3.75	1.78	1.97	4½	11	155	47	----------	--------	0

The following conclusion are drawn from the experimental data which have been tabulated and from the general appearance and feel of the resulting pulps:

A certain excess of sulphurous acid over the amount necessary to form the bisulphite of the base is desirable, first, because it tends to prevent the formation and separation of the monosulphite of calcium, which is extremely hard to wash out and which is liable to cause specks throughout the pulp; second, it is a more economical liquor to prepare. However, too great an excess of free acid is sure to produce a brown pulp similar to those resulting when sulphurous acid is used alone without any base being present. The liquor should contain about twice as much available acid—that is, acid combined as the bisulphite of the base and acid absolutely free, as is combined in the form of the mono or normal sulphite. Such a liquor will allow of digestions at the maximum temperature of 160° and at even higher ones, without danger of burning the chips if no gas is blown off during the cooking operation. A liquor of this composition will complete the cook in from ten to twelve hours if the charges have previously been thoroughly steamed and four hours are consumed in reaching the maximum temperature ultimately carried.

Remarks.—The sulphite digestions were regulated entirely by the temperature and no gas was blown off at any time. The chips were invariably steamed before the sulphite liquor was run in, and just sufficient liquor barely to cover the well-tamped charge was used. A heavy, perforated lead disc placed on top of the wood kept all the chips submerged. No device to induce circulation of the liquor during the boiling was employed. The heat was applied by direct flame and the charge was always left in the digester after the completion of the cook until the following morning. The chips of all the experiments reported in the above table were of a light, salmon color when discharged, and the liquor was a clear brown and still contained free sulphurous acid. The pulp washed and beat easily to nearly white, soft fiber. Analyses of the unbleached fibers given in Table No. 9, page 93, serve to indicate the extent to which the incrusting matters were removed, under the corresponding digestion conditions.

SULPHITE PULP FROM FIBERS OTHER THAN WOOD.

Within recent years numerous attempts have been made to apply the bisulphite or acid treatment to the manufacture of cellulose from the cereal straws; this was pointed out in a previous paper [11] but the siliceous nature of straw has heretofore stood in the way of a satisfactory isolation of the cellulose by this method.

Dietz[12] proposes first to remove the greater proportion of the ash content of the straw before submitting it to the action of the sulphite liquor. He has shown that a preliminary treatment with the theoretical quantity of hydrofluoric acid, calculated on the basis of the silica content of the straw, in the form of a 0.5 to 1.25 per cent solution, is capable of reducing the 1.5 to 3.7 per cent of silica normally present to less than 0.05. After such treatment, the straw is said to be quite suitable for digestion with bisulphite liquors. The best conditions for boiling the straw thus purified are given by an ordinary calcium bisulphite liquor containing 3.6 per cent total sulphurous acid, of which 2.4 per cent is free and 1.2 per cent combined. The boiling should be regulated so that a pressure of 3.5 atmospheres is reached in an hour and maintained for three hours. By this procedure the author obtained a 42 per cent yield of pulp which bleached well with 13 per cent of bleaching powder. Whether the partial removal of the silica in this manner will prove to be economically practicable remains to be seen. The increased yield of straw cellulose and the short time required to produce it, should be considered to be very attractive on the continent, where this material is quite highly prized for paper stock. In view of some results to be described later, obtained in pulping bamboo by means of sulphurous acid, I do not believe it to be necessary partially to remove the mineral constituents from highly silicated materials, before their treatment with sulphite liquors.

Other raw materials besides the Philippine woods already described, from which sulphite pulp has been prepared in this laboratory are hemp waste, old rope, jute gunny sacks and dwarf bamboo. The experiments were conducted with the view of determining the exact conditions conducive of the best results in yield, color, ease of bleaching and strength of the resulting pulps; the conditions of the digestions; namely, strength of liquor, proportion of free and combined acid, proportion of liquor to material digested, temperatures employed and duration of the cooking are given below.

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[11] *This Journal* (1906), **1**, 437.

[12] *Ztschr. f. angew. Chemie.* (1905), **28**, 648.

SULPHITE BAMBOO PULP.

Preparation.—Mature and seasoned culms of dwarf bamboo were crushed between rollers and chopped into 3 to 4 inch lengths. Some charges were thoroughly steamed before the sulphite liquor was added and in others the liquor was run in upon the dry chips. Bamboo prepared in the above manner forms dense, flat pieces which lie very close together and which allow of being covered with considerably less liquor than an equivalent weight of chipped wood. In all the digestions the weight of the bamboo to the weight of the liquor used was $\frac{1}{3.5}$ to $\frac{1}{4}$—that is, 15.12 liters (four gallons) of liquor was the maximum amount employed in any case for 4.5+ kilos (10 pounds) of bamboo chips.

Experiment 1.—Unsteamed chips were gradually heated through a period of four hours to a maximum temperature of 150° C. and maintained at this point for four hours longer, giving eight hours for the entire digestion. The charge was blown out under pressure; the chips were light, salmon-colored and apparently digested. The yield of air-dry pulp was 56.6 per cent. The liquor carried 3.5 per cent of sulphurous acid, all combined as the bisulphite.

Experiment 2.—Five kilos of well-steamed bamboo were covered with 13.23 liters (3.5 gallons) of bisulphite liquor, containing 3.45 per cent of total sulphurous acid, and heated up directly to a maximum of 155°, this temperature being maintained for a total period of ten hours. The chips were soft, light-brown in color, and they bleached with difficulty. The yield of unbleached pulp was 51.7 per cent; the yield of bleached was 48.4 per cent, with a consumption of 22 per cent of bleaching powder of 35 per cent available chlorine.

Experiment 3.—Two and one-half kilos (5.5 pounds) each of steamed bamboo and cupang wood were digested with 15.12 liters (4 gallons) of liquor of the following composition:

	Per cent.
German method:	
Total sulphurous acid	3.6
Free sulphurous acid	2.4
Sulphurous acid combined as monosulphite of calcium	1.2
Lime, CaO	1.05
American method:	
Total sulphurous acid	3.6
Free sulphurous acid	1.2
Sulphurous acid combined as bisulphite of calcium	2.4
Lime, CaO	1.05

The cook was heated up to 155° in four hours and maintained at 145° to 155° C. for a total period of ten hours. The yield of cellulose from the cupang was 46.76 per cent, from the bamboo 47.32 per cent.

Both the cupang and the bamboo fibers were of good appearance throughout, soft and nearly as white as bleached pulp. The bamboo pulp consumed 16.8 per cent of bleaching powder in two treatments; the yield of pure, bleached cellulose being 45.3 per cent. See Table No. 8 for the bleach consumption and yield of bleached cupang fiber. Analyses of both pulps in the unbleached state are given in Table No. 9.

TABLE No. 9.—*Analyses of unbleached sulphite fibers prepared by the quick-cooking process.*

	Moisture (loss at 100° C.).	Resins (solution in alcohol).	Hydrocellulose solution in 1 per cent alkali.	Cellulose.	Non-cellulose (legrin) by difference.	Mineral matter (ash).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Lauan	9.20	0.91	5.77	81.42	2.19	0.51
Mayapis	8.88	.63	6.29	80.57	3.31	.32
Cupang	8.99	.50	4.16	82.60	3.04	.71
Dwarf bamboo	9.08		9.04	72.36	4.37	5.15
	8.57		6.94	78.68	3.67	2.14
Jute (old bagging)	8.07		8.93	79	3.47	.53
Manila hemp (old rope)	8.03		12.02	77.40	1.95	.60
Spruce[a]	6.13–6.70		1.52–4.25	81.31–89.74	.73–9.37	.33–1

[a] The figures for sulphite spruce fiber are the extremes found by Griffin and Little on analysis of four samples of unbleached pulp prepared by the quick-cook process.

MANILA HEMP—OLD ROPE.

Very dirty, 3-inch cable rope cut down and well cleaned and dusted by hand, lost 21 per cent in weight.

Experiment 1.—Digested with a straight bisulphite liquor containing 3.54 per cent total sulphurous acid. A temperature of 140° C. was reached in two hours and held at 140° to 145° C. for four hours more. The fiber was nearly white, clean and strong; the yield of air-dry, unbleached pulp was 72 per cent, calculated on the cleaned material, and 56.88 per cent calculated on the original weight of the rope.

Experiment 2.—3.75 kilos (7.5 pounds) of rope prepared as above and 1.25 kilos (2.5 pounds) of new jute bagging were digested with 15.12 liters (4 gallons) of calcium bisulphite liquor of 3.5 per cent total sulphurous acid content. A maximum temperature of 145° C. was reached in less than two hours and maintained for a total period of six hours. The pulp was clean, grayish and long fibered.

The yield unbleached was as follows: Rope, 71.5 per cent; jute, 62.6 per cent.

Experiment 3.—3.75 kilos (7.5 pounds) of rope of good quality which lost approximately 10 per cent in cleaning and 1.25 kilos (2.5 pounds) of very old jute bagging were digested with a bisulphite liquor of the following composition:

	Per cent.
Total sulphurous acid	3.55
Sulphurous acid combined as monosulphite	1.365
Available acid	1.185

A maximum temperature of 150° was reached in one hour and maintained for three hours—a total of four hours for the entire cook.

The yield was as follows: Rope fiber, 66.5 per cent; jute fiber, 56 per cent.

The chief features of the sulphite pulps made from Manila and jute stock are the light, gray color to be obtained direct from the washing engine.

ABACA WASTE—SULPHITE DIGESTIONS.

Baled waste from hand-stripped Manila hemp from Albay Province was thoroughly hand sorted and dusted to free it from coarse husks and sand; at least 50 per cent of the original weight of the waste being removed by this treatment. It was then cut to a suitable fineness (about 4 to 5 inch lengths) and closely packed into the digester, strong pressure being used to hold the charge submerged in a small volume of liquor. Four to five times its weight of liquor proved sufficient to pulp the material under the conditions of the respective experiments outlined below.

TABLE No. 10.—*Sulphite digestion of abaca waste.*

Experiment No.	Composition of the liquor.			Duration of digestion.		Maximum temperature carried.	Yield of unbleached pulp.
	Total SO_2.	Combined SO_2.	Available SO_2.	Time to reach maximum temperature.	Total time.		
	Per cent.	*Per cent.*	*Per cent.*	*Hours.*	*Hours.*	°*C.*	*Per cent.*
1	3.57	1.76	1.81	2	7	150	48.9
2	3.34	1.30	2.04	2	5	140–145	47
3[a]	3.40	1.50	1.90	1½	6	145	48.75
4	3.6	1.2	2.40	2	5	150	50.76
5[a]	3.55	1.36	2.18	1	4	140	59.2

[a] The charges for experiments 3 and 5 consisted of 8 pounds of hemp waste and 1 pound of jute bagging.

Remarks.—An ordinary bisulphite of lime and magnesia liquor, such as is generally used in the manufacture of sulphite wood pulp, is applicable to this material.

The state of subdivision and the extremely porous nature of the waste, allows of the heating of the boiler to the maximum temperature it is desired to maintain in the shortest possible time, without danger of burning the pulp.

Three to four hours' digestion at temperatures ranging between 140° and 150° C. will produce a strong, gray-colored stock which washes and beats readily by the usual methods, but these conditions of time and temperature do not dissolve all of the chaff and cellular matter present, and the result is a rather poor appearance when the pulps are molded into boards or sheets. The cellular matter remaining in the pulps is nonfibrous and has no felting power, but it does possess a cementing nature which adds to the strength of paper made from such half-stuff and I do not think that it will be necessary to attempt to remove all of the nonfibrous portions from hemp waste for the production of colored or coated papers such as are used in the manufacture of heavy bags which are filled but once and where strength is the important characteristic desired.

The bale of waste upon which the above experiments were made is not considered to be as clean and well sorted as it is possible to obtain this material in practice, in fact I am informed that a much better grade is now being collected and baled in considerable quantities in the provinces.

An average yield of approximately 50 per cent of strong-fibered stock was obtained in the sulphite digestions outlined above, and this is about what may be expected from the best grades of waste it is possible to obtain, if the baled stuff is thoroughly deviled before it is subjected to any kind of chemical treatment.

General conclusions.—First. It is essential that the material should be clean and as free from foreign matter as mechanical cleaning processes will make it.

Second. A preliminary steaming of the charge in the boiler before the sulphite liquor is run in is advantageous mainly because it allows the material to be tamped down and covered with a much smaller quantity of liquor. Most of the materials treated are very bukly in the dry state and sufficient liquor to cover is greatly in excess of the amount necessary to do the work. The running in of cold water and allowing it to discharge answers the purpose.

Third. Because of the finely divided and porous nature of such materials, no gradual rise of temperature up to the maximum to be carried is necessary, as is true in treating dense, wood chips, but the digester may be heated up to full pressure at once, thus saving three to four hours in time.

Fourth. The stock is more easily washed and its color, as it appears when it is taken direct from the washing engines, is fully as light as the partially bleached lime or soda pulps made from this class of fibers, and this fact should be strongly emphasized not only because of saving in cost and of the time of a bleaching operation, but also because lignified fibers such as hemp, jute, etc., are very susceptible to chlorination during bleaching, and this seriously impairs the strength of the resulting stock.

I am not aware that sulphite jute or rope stock have ever been made commercially, but I see no reason why such stock would not be superior to that made by the old process, particularly as this class of fibers is invariably used in the manufacture of low-white or coated products, in which strength is the most important consideration. Mills running on jute, rope, straw, etc., will readily see the advantage of employing a process which cooks and bleaches a fiber in one operation, thus eliminating the losses of fiber and time incident to extra handling and excluding the solvent action on the fiber which alkaline liquors are known to possess, as well as the liability to deterioration in strength caused by poorly conducted bleaching.

COMPARISON OF THE ACID AND ALKALINE PROCESSES OF PULP MANUFACTURE.

Some of the points of superiority claimed for the acid or bisulphite method of treatment are: greater yields, stronger fibers and greater economy in the cost of chemicals consumed. The adherents of the older, or alkaline method of treatment claim applicability to a wider range of raw materials, greater ease of manipulation and economy in cost of chemicals and time. There is no doubt but that greater yields and stronger stock are obtained by the bisulphite process, for as it is strictly a hydrolytic chemical reaction performed in a reducing atmosphere, the possibilities of oxidation are excluded, and therefore no loss of cellulose or weakening of the fiber results from this cause.

White pine wood, which is pulped by both processes, invariably in commercial practice yields about 10 per cent more sulphite than soda cellulose. Sulphite cellulose, in the common practice of blending different pulps to produce papers of certain qualities required by the trade, is relied upon for the property which it possesses of giving strength to the materials.

That alkaline solutions exert a solvent action on vegetable fibers is well known. Taus[13] in a series of carefully conducted experiments has shown that purified cotton cellulose is attacked by alkalies at the high temperatures and concentrations frequently employed for isolating paper cellulose by the soda process, and assuming that a soft wood (pine wood) contains 54 per cent of cellulose and 46 per cent of other matter, the latter or 46 per cent will be dissolved after three hours of digestion with 3 per cent caustic soda solution at a pressure of five to six atmospheres, but 70 per cent of the total cellulose and other matter would be dissolved with the same strength of liquor in the same period if the digestion were to be carried on at ten atmospheres, and approximately the same solvent action is effected if the time (three hours) and the pressure (five atmospheres) remain unchanged, but the strength of the alkaline liquor increased to 8 per cent. Now 8 per cent (12° Baumé) liquor is the rule rather than the exception in the actual practice of soda wood pulp production, and for the purpose of facilitating the mechanical loosening of the fibers and of effecting solution of the noncellular incrusting matters in the shortest possible time, pressures which are more nearly ten than five atmospheres are also adopted. In my opinion more thorough and better methods of preliminary preparation of woody tissue or of other raw cellular materials will accomplish the same purpose with an improvement both in quantity and quality of the resulting product. In all the experiments I have recorded on both soda and sulphite digestion of wood, the method of preparation—that is, the barking and chipping which are employed in actual practice—was followed, but repeated trials on wood in various states of subdivision conclusively showed that it was possible to produce an equivalent yield with a considerably weaker liquor in the same time, by doubling the number of chips per given weight. While there undoubtedly is a minimum limit beyond which wood could not safely be divided without impairing the length and strength of the fibers, that limit is by no means reached in present practice. Even the passing of the green, chipped wood under heavy crushing rollers, a procedure worked in some sulphite mills, is a very efficient means of mechanical disintegration.

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[13] *Dingler's Polyt. Journ.* (1890), **276**, 411–428.

The method of preparing wood for sulphite digestion and the improvements in the operation itself have resulted in a great saving of the time required for the digestions. It was usual, when the process was first applied, to boil the pulp for twenty hours or more, but now fourteen to sixteen hours, dependent upon the kind of wood and the quality of the pulp desired, is the more common practice.

Much has been written regarding the relative cost of the two processes of manufacture under discussion. Many factors enter into a calculation of the comparative cost of producing soda and sulphite cellulose. However, the problem is an important one in the event of the introduction of the industry in a new country and therefore it deserves some consideration. Leaving out the initial expense of installation, which is undoubtedly greater for a sulphite than for a soda plant, it is proposed briefly to discuss the relative cost of producing a ton of sulphite and soda pulp from white lauan or mayapis wood, the local market quotations on the chemicals required alone being considered.

Calculations for the production of 1 ton of sulphite pulp, based on the use of a straight bisulphite of calcium liquor of 3.5 per cent total sulphurous acid content and 1 per cent of lime, Japanese sulphur and native lime being used, are as follows:

Fifteen per cent of sulphur recovered; 2 cords of wood give 1 ton (2,000 pounds) of pulp; 8,399.16 liters (2,222 gallons) of liquor contain 295.3 kilograms (650 pounds) sulphurous acid, or 155.4 kilograms (341.88 pounds) of sulphur.[14]

Sulphur is calculated at 2.75 cents per kilogram (1.25 cents per pound)	$4.27
And 84.08 kilograms (185 pounds) lime, at 1.1 cents per kilogram (0.5 cent per pound)	.92
	5.19
15 per cent of sulphur recovered—that is, 23.33 kilos (51½ pounds)—at 2.75 cents per kilo (1.25 cents per pound)	.64
	4.55

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[14] Ninety-five per cent of the sulphur burned being rendered available in the form of sulphur dioxide.

The calculations for the production of 1 ton (2,000 pounds) of soda pulp are based on the use of caustic soda made from imported soda ash and native lime. They are as follows:

7,560 liters (2,000 gallons) of caustic liquor of a specific gravity of 1.06 (8° Baumé, 5.25 per cent of caustic soda) contains approximately 400 kilograms (880 pounds) of alkali, which in turn requires for its manufacture:

300 kilos (660 pounds) lime, at 0.22 cent per kilo (0.5 cent per pound)	$3.30
534 kilos (1,176 pounds) soda ash, at 0.4 cent per kilo (1 cent per pound)	11.76
	15.06
75 per cent of soda ash recovered as such, 400 kilos (882 pounds), at 0.4 cent per kilo (1 cent per pound)	8.82
	6.24

While the above estimates are but rough approximations, they are to be considered as fairly conservative and they serve to indicate the cost of the crude chemicals actually consumed in the production of one ton of sulphite and soda pulp respectively. It will be noted that estimates for the sulphite liquor call for a consumption of 8,399 liters (2,222 gallons) for 2 cords of chips. In our sulphite digestions we were able to cover 4.54 kilos (10 pounds) of well-packed chips, previously steamed, with 18.90 liters (5 gallons) of liquor; this is equivalent to the above volume for 2 cords of the wood. However, in practice 9,450 liters (2,500 gallons) of liquor are usually employed. The sulphite liquor in the estimate and the one which was found to produce the best results in our experiments had the following composition:

	Per cent.
Total sulphurous acid	3.5
Sulphurous acid combined, bisulphite of calcium	2.28
Sulphurous acid free (in excess of the amount necessary to form calcium bisulphite	1.22
Lime	1.00

In Germany, all acid in excess of that which is necessary to form the monosulphite of calcium ($CaSO_3$) is termed free acid; hence according to the German system of nomenclature, the above liquor would contain:

	Per cent.
Combined acid	1.14
Free or available acid	2.36
Total acid	3.50

PULP- AND PAPER-MAKING CHEMICALS.

The following chemicals, *lime, sulphur, caustic soda, soda ash, chloride of lime, kaolin, talc, gypsum, alum,* etc., are largely consumed in the manufacture of paper pulp, their use being dependent upon the chemical process adopted for the conversion of raw fibrous material into paper stock and the particular grades of the finished product it is desired to make.

LIME.—Calcium oxide (CaO), commercially known as quick or caustic lime, is undoubtedly the most universally used reagent in the preparation of chemical pulp. Its source is the limestone deposits so widely distributed throughout the world. In the alkaline process of digestion, lime finds extensive use, either as such or in combination with soda ash for the preparation of caustic soda, when a more active alkaline reagent is required.

In the acid or bisulphite method of treatment, lime is the base most generally employed in the preparation of the sulphite liquors, here again it may either be used alone to form unmixed bisulphite of calcium liquors, or in conjunction with magnesia derived from the magnesian limestone, called dolomite.

A further use for lime in the paper industry is in the manufacture of bleaching powder (chloride of lime) and it may be employed in the form of the sulphate, as pearl hardening or as gypsum to furnish a mineral loading material in certain grades of paper.

SULPHUR.—The principal sources of the world's supply of sulphur are found in Sicily, in Louisiana and Utah in the United States, and in Japan. In the form in which it is brought on the market it is classified according to its degree of fineness. A second or third grade, containing one-half to one per cent of foreign matter and ash, is usually employed in the preparation of sulphite liquors. Sulphur comes to the mills in sacks or barrels and it is burned as needed, the sulphurous acid gas which is formed either being passed into water containing the lime in solution or suspension, or through a long vertical column of coarse limestone or dolomite, sprinkled with water.

CAUSTIC SODA AND SODA ASH.—Caustic soda ($NaOH$) and soda ash (Na_2CO_3) appear on the market in different states of purity, their value depending on the amount of alkali (Na_2O) present. The grades which find most general use among paper makers are 78 per cent caustic soda and 48 per cent ash.

The present market quotations are as follows:[15]

Caustic soda (78 per cent), per cwt	$1.75–1.85
Soda ash (48 per cent), per cwt	.75– .80

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[15] The duty on these chemicals on entering the port of Manila is 25 cents per 100 kilos (220 pounds) gross weight. (Philippine Customs Tariff, Par. 93.)

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Bleaching powder (chloride of lime) is valued on its content of available chlorine; it is somewhat unstable and it readily deteriorates in strength on exposure to heat, air and moisture. When freshly prepared it contains about 40 per cent of available chlorine. Analyses of several samples of bleaching powder purchased in the Manila market have shown a strength of less than 30 per cent in every instance. In view of this loss which bleaching powder undergoes during long periods of transit, it is questionable whether it would not be more economical to import the liquid chlorine and manufacture bleaching powder here as needed.

The older method of gas bleaching, making use of chlorine in the gaseous form, was displaced by the use of chlorine in combination with lime because of the simplicity and ease of control of the operation with the latter, but with bleaching powder at $1.25 per hundredweight and because of its arrival in Manila at a point nearer 20 than 30 per cent in strength, it could not compete with liquid chlorine at its present market quotations.

About one-half of the world's output of bleaching powder is prepared from chlorine made by electrolyzing crude salt. Crude salt from sea-water evaporation is both cheap and plentiful.

Mineral fillers.—Nearly all kinds of paper contain varying amounts of some form of mineral matter. These are added to the pulp in the beating engines for the purpose of increasing the weight, filling up the pores and imparting a better feel and appearance to the finished sheet. The substances best suited for these purposes are certain grades of clay, sulphate of calcium, talc, gypsum, barytes, etc. They should be of light specific gravity, free from grit and should be white, showing a low content of iron and organic impurities.

The Mining Division of the Bureau of Science submits the following data concerning the local supply of crude chemicals, their cost and availability:

Limestone.—The sources of supply of burned lime for Manila are (*a*) the limestone quarries near Binangonan on Laguna de Bay in Rizal Province and (*b*) a coral limestone from marine shells burned near Malabon on Manila Bay.

(*a*) The quarries at Binangonan have a present annual output of about 600 tons, mostly of water-slaked lime which is sold in Manila for making mortar. This lime can be obtained fresh burned when it is needed, as is the general custom throughout the Archipelago. The product is a very fat lime, which swells when it is slaked to about three times its original volume. The lime is valued at Binangonan in proportion to its content of calcium oxide. The present prices are as follows:

Quick lime, per cavan (about 80 pounds)	₱1.35
Slaked lime, per cavan (about 80 pounds)	.45

The transportation charges from Binangonan to Manila are ₱0.15 per cavan, which make the prices in Manila ₱1.50 and ₱0.60 per cavan for the quick and slaked lime, respectively. As there is a profit in this of about ₱0.60 per cavan for quick lime and ₱0.17 for slaked lime, it will be seen that if the consumer were to burn his own lime, under present conditions it would cost about ₱0.90 per cavan of 80 pounds in Manila. This is one cent Philippine currency or one-half cent United States currency per pound. This rate is excessive, but it is obtained under conditions of manufacture and transportation which are of the crudest description. With a modern plant, running under favorable conditions as regards quarrying, fuel and labor, I can see no reason why quick lime should cost more that one-half of this figure.

(*b*) At Malabon about 600 tons of slaked lime are also produced annually. This, like other lime obtained along the shores of marine waters, is derived from coral. It is produced at Malabon for ₱0.25 per cavan, and it costs ₱0.38 per cavan in Manila. The greater part of it is used for mortar and whitewash. Other points near Manila where lime is being burned are Malolos, Angat and Baliuag in Bulacan Province and at Sexmoán and Guagua in Pampanga. In general, a limestone belt extends from Binangonan in Rizal Province north through Bulacan and into the Province of Nueva Ecija. The Cabanatuan branch of the Manila and Dagupan Railroad runs nearly parallel to it and through the towns where quarries are at present situated and it is firmly believed that a practically unlimited supply of good lime will readily be available for economic use when the occasion demands. Other localities upon which definite information is at hand concerning the extent of the deposits of limestone and their accessibility include the islands of Batan, Romblon, Cebu and Panay. The limestone deposits of Batan Island are particularly of interest from the standpoint of their use in the manufacture of paper, because of their proximity to the coal fields and also because of their location with respect to the most promising available supplies of raw material, namely the Manila hemp growing districts.

An exceptionally pure limestone is found in northern Panay, outcropping in large masses on both banks of the Badbaran River between Dumarao and Maabutang and also about 4 miles from the former place, which lies on the line of the proposed railroad from Iloilo to Capiz. Old lime-kilns used by the Spaniards for burning this stone are near by. This limestone is cream colored, compact and semi-crystalline, with a low iron and silica content. A large deposit of very pure limestone occurs near Pilar on the north coast of Panay, it is very similar in appearance to the other Panay limestone which has just been described, and it should prove well fitted for the manufacture of quick lime. It is situated in the center of a large mangrove forest from which any quantity of cheap fuel could be obtained, and being close to the sea the problem of transportation is minimized.

The following table gives the results of analyses of some Philippine limestones:

Table No. 11.—*Analyses of some Philippine limestones (calculated to calcined material).*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica (SiO_2)	1.06	2.19	0.49	1.55	0.89	2.49	0.37	0.57	1.15	0.62	0.01
Iron (Fe_2O_3)	.29	.24	.38	.82	.39	.90	1.25	.26	.67	.84	.29
Lime (CaO)	94.80	94.24	98.12	96.34	97.41	94.62	96.88	97.00	96.92	95.91	97.39
Magnesia (MgO)	1.96	2.44	.98	1.27	.48	.21	.72	1.40	1.24	.51	2.39

Note.—Numbers 1 and 2 are from Anabang near Angat and from Santa Margarita Springs respectively, both in Bulacan Province, Luzon; 3 and 4 are from the quarries near Binangonan, Rizal Province, Luzon; 5 and 6, from Batan Island near Legaspi, Albay Province, Luzon; 7 and 8 are taken from near Dumarao and Pilar, Capiz Province, Panay; 9 is a coral limestone from Malabon on Manila Bay; 10, a suitable causticizing lime; 11, a suitable liquor-making lime.

LOADING MATERIALS.

Kaolin.—While but little prospecting work has been done on the clay deposits of the Philippines, there seems little doubt but that the supply which may be obtained is so extensive that the question of importing this crude chemical will never arise. A general inquiry concerning Philippine clay deposits for the purpose of establishing a school for pottery making has been begun by the Bureau of Education and a systematic study of the physical and chemical properties of various clays for different economic uses is under way in this Bureau at the present time. Below is given the chemical composition of some clays from Laguna Province and from the Island of Romblon:

Table No. 12.—*Chemical composition of some clays from Laguna Province and from the Island of Romblon.*

	1.	2.	3.	4.	A.	B.	C.	D.
Moisture, loss at 100°-110°	0.30	10.15	7.09	9.10	1.60	1.24	2.66	0.63
Loss on ignition	12.27	10.77	11.27	12.79	12.56	12.67	13.50	13.73
Silica (SiO_2)	47.56	42.77	43.50	41.16	44.30	45.24	44.15	47.76
Aluminia (Al_2O_3)	38.12	33.48	35.48	35.84	38.64	37.59	36.54	37.04
Ferric oxide (Fe_2O_3)	0.08	1.04	Trace.	.67	.83	1.00	1.04	.75
Lime (CaO)	.39	1.61	.17	.42	.39	.66	.15	.06
Magnesia (MgO)	0.0	.16	.41	.02	.42			.14
Alkalis (Na_2O, K_2O)	1.28	.11	2.08		1.18	1.69	.98	.52
Specific gravity	2.8625	2.5585		2.5451	2.91			2.46

Note.—Numbers 1, 2, 3, and 4 are taken from Griffin and Little,[16] as suitable clays for paper makers; A, B, and C are Philippine clays from Laguna Province; D is from Romblon.

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[16] Chem. Paper Making: (1894) 316.

Agalite, or ground talc, as it is commonly termed, has come into extensive use as a mineral filler in paper manufacture. Like asbestos, it has a distinct fibrous structure which causes it to blend well with the vegetable fiber of the pulp and thus to be retained without the considerable loss incidental to the use of china clay or sulphate of lime for this purpose. The more valuable talc for paper loading consists of altered tremolite, the fibrous structure of which is largely retained. According to the statistics of the New York State Geological Survey for 1905, there were produced 67,000 short tons of fibrous talc, valued at $469,000, or an average of $7 per ton. Practically the entire output finds its way to the paper mills. Tremolite from Ilocos Norte, Luzon, was examined in the Division of Chemistry, Bureau of Science. It consisted of irregular, foliated masses of a beautiful greenish-white tint. Ground in a ball-mill and then passed through a sieve of 100 meshes it is a greenish-white impalpable powder with a very soapy feel. It appears as minute, elongated crystals or fibers when seen under the microscope. Its chemical composition, compared with that of a commercial talc, is as follows:

	Water (loss on ignition).	Silica (SiO_2).	Alumina (Al_2O_3).	Ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Specific gravity (Joly balance).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ilocos Norte altered tremolite	2.33	57.62	1.66	1.36	13.38	24.18	2.84
Agalite	2.67	61.82	1.59		3.65	29.98	2.6–2.8

The specimen which was examined, when judged by its physical properties, would be considered of very good quality for the purpose of the paper manufacturer. It is easily ground, is of good color and is especially free from grit.

No definite figures with respect to the extent of the deposit can be given. However, it has the advantage of being situated near the sea and development work should show large pockets of talc in connection with mica.

Sulphur and pyrites.—Although sulphur is found widely distributed throughout the Philippine Archipelago, careful search has failed to locate any deposits of commercial importance. The most favorable outlook for native sulphur is from near Barauen in Leyte and from the Island of Biliran, which, on superficial examination, show 3,000 and 400 tons of sulphur in sight, respectively, but both these deposits are too small to warrant the necessary cost of extraction and transportation.

Pyrites.—The only deposit of this mineral of any extent and so far reliably reported, is in Lepanto Province, and here again the question of transportation, for the present at least, throws it out of reckoning as a commercial possibility.

Japanese sulphur.—The nearest and no doubt cheapest source of a supply of sulphur for industrial use in the Philippines, is Japan. The output of the Japanese sulphur mines for 1904 was 20,000 tons. About three-fourths of the total product is exported, the United States of America and Australia being the chief consumers. Recent quotations are $17.50 a ton for the best grades and $15.50 for seconds and thirds. As the yield of sulphur from Japanese ore is probably the highest in the world, this cost will allow it to be laid down in Manila, duty prepaid, at a price but slightly if any in advance of the market quotations on American sulphur. The fact that Japanese sulphur enters the United States in competition with the home product bears out the above statement. Five samples of Japanese refined sulphurs submitted by the Mitsui Bussan Kaisha were found to assay from 99.3 to 99.82 per cent in extremes of fineness.

FUEL.

Coal of a fairly uniform quality is found widely distributed throughout the Islands. The largest known deposits are located on the Islands of Batan, Cebu and Polillo, but it also occurs in greater or less quantities in Negros, Mindanao, Samar, Masbate, Mindoro, and in the Provinces of Rizal and Nueva Viscaya on Luzon.

Recent work [17] in this Bureau on the Philippine Coals has shown that they are of much better quality for steaming purposes than was hitherto supposed, and that the poorer grades are very satisfactory from the standpoint of producer gas manufacture.[18] For more detailed accounts of the distribution and fuel properties of Philippine coals, see The Coal Deposits of Batan Island [19] and The Coal Measures of the Philippines.[20]

Wood for fuel is both cheap and abundant in many localities. The principal source of firewood is found in the widely distributed mangrove swamps of the seacoast. The mangrove forests are composed of a number of trees which produce dye and tan barks for local use and in which there is some trade. Work on Philippine mangrove tan barks is in progress in this Bureau and it is believed that they will compare favorably with the similar species which are handled commercially in Africa, Borneo, Java and elsewhere. An exploitation of mangrove tan bark will materially increase the available supply of cheap fuel for lime burning and other industrial purposes.

Oil for fuel.—The possibility of the use of oil as fuel in the Philippines is as yet uncertain, although a small quantity of oil is known to exist in Tayabas Province, Luzon, and gas has been encountered in drilling artesian wells in Pampanga Province.

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[17] Cox, A. J.: *This Journal* (1907) **1**, 41.

[18] Cox, A. J.: *Ibid.* (1906) **1**, 877.

[19] Smith, D. D.: *Phil. Mining Bureau Bul.* Manila (1905) No. 5.

[20] Burrett, C. H.: *U. S. War Dept., Div. Ins. Affairs, Bul.* (1901).

PAPER MILL WATER.

Large quantities of water are required in the manufacture of pulp and paper, and its quality is of the first importance. In no other industry making use of large quantities of water in the processes of manufacture, is the purity of the water more carefully guarded. A soft water is not demanded for making the liquors used in the boiling of stock, because it is necessarily rendered hard in the operation. For washing the pulp and for steam-making purposes a soft water is desirable and even necessary. The importance of using a very soft water in the other departments of paper manufacture is perhaps overestimated. It is of more concern that the water be clear and especially free from iron, sediment and organic matter. A factory making use of the waters of small streams will be troubled by turbidity during the rainy season of the year. A better source would be in wells or reservoirs fed by pure water brought by conduits from mountain streams. Artesian wells furnish the greater supply of water in use here at the present time for boilers and industrial purposes.

A series of fifty-two analyses of the Manila city water supply, extending over a period of seven months and representing portions of both the dry and rainy seasons gave the following extremes in parts per million:[21]

	Maximum.	Minimum.
Total residue	220	153
Fixed residue	190	127
Volatile matter	46	16
Oxygen consumed	2.20	.65
Chlorine	4.40	2.13
Hardness	109	58.8

Remarks.—The above analyses[22] were made on unfiltered water and they show a high degree of purity. The oxygen consuming power, equivalent to bleach consuming power, is remarkably low. The source of this supply is the Mariquina River which empties into the Pasig River between Manila Bay and Lake Laguna.

The mineral constituents of a water affect its value for paper or pulp manufacture mainly as they bear upon its suitability for boiler purposes. Philippine ground and surface waters as a class are considered to be moderately hard.

While none of the boiler waters which were examined contain sulphate of calcium, some of them have a high silica content which forms a troublesome scale.

A table of analyses of boiler waters collected from various provinces and islands of the Archipelago is given on page 106.

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[21] Parts per millon × 0.058 = grains per United States gallon.

[22] Bliss, C. L.; *Publications of the Bureau of Government Laboratories* (1904) No. 20.

TABLE No. 13.—*Analyses of some Philippine waters.*

[Parts per million, which multiplied by 0.0058 gives grams per United States gallon.]

Laboratory No.	Total residue.	Volatile residue.	Fixed residue.	Nonscale-forming ingredients.	Scale-forming ingredients.	Silica, SiO_2.	Fe_2O_3 Al_2O_3.	CaO.	MgO.	SO_3.	Quality.	Source.
3545	2,248	1,081	1,167	807	360	43.3	17.6	195.2	142	Trace	Moderately hard	
3601	949	48	901	554	347	38.8	Trace	159.4	55	58	Soft	Cebu.
35025	483.5	118.5	365	178.8	186.2	30	4	62	26.5	28.46	Hard	Jaro River, Jaro, Iloilo Province, Panay.
37929	359.1	32.4	3,267	74.1	252.6	37.6	1.4	87.8	39.4	1.3	Moderately hard	Cebu.
5100	1,757	40.80	1,716.4	1,499.3	217.1	55	.4	65.1	1.2	89.66	Hard	Isla del Provisor, Manila.
4673	2,583.8	68	2,515.8	2,381.4	134.4	27	10.80	53.8	29.2	2.74	do	Artesian well, Quarantine Station, Cauit Island, Cebu.
4001	1,499	25	1,474	1,398.5	75	41.75	1.50	11.25	12.61	92.34	do	
4503	1,629	52	1,577	1,481	96	37	2	13	19.47	4.12	do	Cebu.
	215.4					44.7	6.8	23	9	15.6		Manila water supply.
	153	24	129				.25					Pampanga River, near Calumpit, Luzon.
	391.6	4.2	387.4	71.7	315.7	46.4	.4	133	23.49	3.09		Cebu (terminal) R. R.
37929 (*a*)	389.7	5.2	384.5	94.1	290.4	24.5	1.3	128.7	17.1	3.3	Hard	Cebu.
37929 (*b*)	348.5	21.5	327	86.7	240.3	22.9	1.5	97.8	12.8	7	do	Do.
37929 (*c*)	359.1	32.4	326.7	74.1	252.6	37.6	1.4	87.8	39.4	1.3	do	Do.
35024	348.1	141.5	406.6	157.8	248.8	56.6	4	65.2	28.19	38.06		Jaro River at Lapaz, Iloilo Province, Panay.

WATER POWER.

Abundance of water power in the past has been a more important factor in determining the location of paper mills than the nearness to the source of raw materials or to the market. At the present time this applies more particularly to plants producing mechanical or ground wood pulp. Steam is necessary for the manufacture of chemical pulp as it is used for heating the digesters and it also furnishes a much more efficient and easily controlled power for running paper mill machinery. There is an abundance of water power in the Philippines, but the cost of installing plants and their location with respect to the commercial centers precludes its utilization at the present time.

MARKETS.

The market in the Philippines.—The first consideration of the new industry would manifestly be to supply the home market with those grades of paper for which the raw materials are best suited. The annual imports of paper of all kinds into the Philippine Islands approximates $1,000,000 in value and the demand for newspapers, magazines and books is multiplying yearly. This increased demand is but the natural result of the growth of the public school system throughout the Islands, which creates a greater desire for the knowledge of Western countries. The main items of the total importation are pulp, writing, printing and wrapping papers, all of which could largely be produced from native raw materials. The local supply of cotton and linen rags could be drawn upon for the finer grades of writing and note paper. No other city of its size in the world is so large a consumer of cotton and linen textiles as Manila. For the greater part, these are bleached and unadulterated with woolen fiber, so that the very best grade of paper rags could no doubt be collected here in considerable quantities.

The foreign market.—Japan is a large importer of paper, approximately $2,750,000 in value having been brought into that country in 1905. Japanese paper is principally made from rice straw and from the bark of the mulberry, but the demand for wood pulp has increased so greatly in the last four or five years that the Japanese Government has begun a systematic study of the suitability of Japanese timber for the purpose of manufacturing this article.

In China, the trade in paper has also attained considerable dimensions, statistics for 1905 showing importations approximating $2,000,000 in value. Foreign capital has recently entered the field for the purpose of manufacturing paper from bamboo, rice straw, etc., so as to meet the rapidly growing trade. The nearness of both the Chinese and Japanese markets should enable Philippine manufacturers to obtain at least a share of the trade in this commodity.

FURTHER OBSERVATIONS ON THE DISTRIBUTION AND AVAILABILITY OF THE RAW MATERIALS WHICH WERE DISCUSSED IN THE ENTIRE SERIES OF ARTICLES ON THIS SUBJECT.

MANILA HEMP (ABACÁ) WASTE.

A considerable quantity of Manila hemp waste has been exported from the Islands since my work on the suitability of this material for paper making was published; thus the problems incident to its collection, curing, sorting, baling and transportation are being solved by the commercial interests involved. It remains to be seen whether the costs of baling and transporting large quantities of waste from the abacá growing districts to Manila and thence to New York or London will allow of this material being economically exported. Fundamentally, it is contrary to commercial practice to attempt to export such a cheap and bulky commodity for long distances, particularly when only about 40 per cent of a given weight is of any value for the purpose for which it is intended. It is self-evident that if this raw material were pulped on or near the place where it is produced, the reduction in the cost of baling and shipping would allow a more attractive price to be paid for the material itself, and better methods of curing and sorting could be inaugurated.

In my opinion the reduction in cost of freight and handling incident to placing abacá waste half-stuff on a foreign market, thus allowing a greater outlay in properly preparing the waste for the digestion process, is certain to bring better results if the quality of the resulting product alone is considered, than would the exportation of the raw product. To pulp the waste here for subsequent exportation would effect a reduction of 50 per cent in freights alone. The initial cost and daily running expenses of an hydraulic baling press would nearly offset the cost of equipment for a pulp mill of 10 tons daily capacity.

COGON GRASS.[23]

Distribution.—The following data with reference to cogon grass are taken from a report of observations on paper materials in Tarlac made by myself while traveling over that province in December, 1906. Cogon of good quality is found between Capas and Concepcion, Tarlac Province, Luzon; the country is level, consisting for the most part of deserted rice and sugar lands which contain some scattering scrub timber. A good road of 7 miles, with but one ford, connects the two places. The two grasses, cogon and taláhib, are almost invariably found together, the predominance of one over the other depending upon the altitude, the taláhib being more plentiful in low places. At this season of the year taláhib has flowered and is rapidly drying and becoming worthless.

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[23] See Richmond, Geo. F.: *This Journal* (1906), **1**, for the discussion of cogon and taláhib as materials for paper making.

Cogon being partially protected from the sun by the taller taláhib is more green and thrifty.

From Capas to O'Donnell the road runs 10 miles to the west, slightly up grade but fairly level; the region is entirely uncultivated; it is too high for rice and too poor for sugar; much grass grows everywhere, but it is of an inferior grade, due to lateness of the season.

There is a good bull-cart road for about 7 miles east from the town of Tarlac in the direction of La Paz; the country is level, the first 3 miles being under cultivation in rice; a mile of quite dense woodland occurs and then 3 miles of uncultivated country follows, covered with a good quality of grass. The country is more rolling and hilly from Tarlac westward in the direction of Moriones, with grass everywhere, pure in the valleys but contaminated with buffalo grass on the hills. The natives informed me that cogon, called *ilib* in Pampanga, is not eaten by horses and cattle, but that they do forage on the young shoots of taláhib.

Practically all the houses in Tarlac Province, with the exception of those in the towns on the railroad, are constructed of cogon. Taláhib is scarcely ever used for this purpose, but the latter finds some employment in the construction of fences for yard and garden inclosures. I observed large stacks of cogon in the various barrios. The natives know when and how to harvest this grass, having learned this because nipa is too expensive for general use as a roofing material in all localities distant from the tide water. Too much stress can not be laid upon the fact that the people who must be depended upon to supply the demand for this grass for any future economic use, are already familiar with its habits of growth and the best methods of harvesting and curing it, and although the present employment of this material for house thatching is general throughout the Archipelago, yet the amount so used amounts to but a small fraction of the quantity which could be obtained under systematic methods of collection.

In my opinion it is absolutely out of the question to cut the grass by machinery in Tarlac Province and it is not advisable to bale it where it grows. If cut with sickles or short grass scythes and tied into bundles of about 20 pounds each, it is easily handled. One day in the sun is sufficient to cure the grass, then it may be loaded on carts and hauled to the railroad station. One native draft animal will haul 500 to 750 kilos (1,100 to 1,650 pounds) of rice and this weight of grass bundles is not too bulky for the carts now in use, if they are supplied with some kind of a bamboo rack. I have frequently seen ton lots of clean grass tied in many neat bundles 20 to 30 centimeters (8 to 12 inches) in diameter stored under roofs for future use.

The effect of decreased bulk upon freight rates up or down the road to the factory site would determine whether straw presses should be located at points on the railroad. I believe that it would be perfectly feasible to collect this grass in car lots at several places along the main and branch lines of the Manila and Dagupan Railway; for instance at Capas and Tarlac the surrounding grass lands are tapped for from 5 to 10 miles each in two directions by fair roads at the season of the year when the grass is at its best, and before it is dry enough to be fired. One plan would be to erect bamboo framed storehouses with iron roofs near the freight tracks at these stations, for the storage of the grass as it is hauled in from the surrounding country.

Cogon grass is abundant and of good quality in the Visayan Islands. Thousands of acres of rolling lands are covered with even stands of tall, thrifty, cogon grass in Masbate and on the Island of Burias. Here the lay of the land is such that heavy draft mowing machinery could be used to advantage.

A practical phase of the utilization of Philippine perennial grasses would be in the material benefit to the forests, as the protection and cutting of the grass areas would greatly decrease the annual loss of forests by fire.

Cogon grass is not jointed like the cereal straws, which constitutes a great advantage in its use for paper pulp; its yield is 5 to 10 per cent higher than that of the latter, it is more easily pulped with the use of a less proportion of caustic soda. Another advantage is that in general, plants which are designed for fiber production should be harvested before the stems are fully mature; this is impossible when the plant is grown for production of grain, as is the case where straw, hemp, flax, etc., are utilized.

I have been asked what price could be offered for cogon grass as a paper material. This is very difficult even to approximate. It depends largely upon whether the grass were to be pulped and manufactured into paper for local consumption, or simply pulped for exportation, in which latter event it would have to enter in competition with chemical wood pulp. The average price paid for American pulp wood in 1905 was ₱11.10 per cord ($5.55 United States currency). A cord of pulp wood and 1,000 kilos (1 metric ton) of grass will produce approximately the same amount of unbleached pulp, namely 1,000 pounds; but the grass is easier handled, is fit for immediate immersion in the digesting vats, and it can be pulped by the same process of treatment, with one-half the expense in time and cost of chemicals. Furthermore, grass pulp will bleach to a good white with 6 to 12 per cent of bleaching powder, whereas wood pulp requires 12 to 25 per cent.

I would estimate that a paper pulp mill, if assured of a continuous supply of a sufficient quantity of clean grass, could pay approximately 1 peso (50 cents United States currency) per picul (137½ pounds) of clean, dry grass laid down at railway or waterway transportation. This is slightly in advance of the average price of American pulp wood.

INITIAL COST OF PULP AND PAPER MILLS.

Because of numerous inquiries from local sources on the probable initial cost of pulp and paper mills, it was thought best here to include some approximate estimates for the benefit of those interested. They are as accurate as the means at our command will permit them to be, but they must not be considered as being other than rough approximations.

Preliminary estimate of a 10-ton sulphite wood pulp mill.

One digester, lined and fittings complete	$9,000.00
Liquor making system, pumps, reclaimer, lead piping, gas coolers	9,000.00
One steam boiler for digester cooking	2,700.00
One centrifugal screen	1,350.00
One flat screen for tailings	300.00
Wood preparing machinery and knotter	4,275.00
Stock chests and stock pumps	1,000.00
Piping, steam fittings, shaftings	3,500.00
Fire and water pumps	850.00
Miscellaneous	1,800.00
	33,775.00
Plus 15 per cent for erection	5,066.25
	38,841.25
Power required, 200 horsepower, which if developed by steam will cost in addition to the above amount	5,000.00

It must be borne in mind that a 10-ton plant requires nearly as costly machinery as one much larger, and in many other ways a 20-ton plant is to be considered more economical.

Preliminary estimate of a ten-ton soda wood pulp mill.

One steel digester	$4,000.00
Liquor making system, pumps, evaporators, causticizing tanks, calcining furnace, etc	5,000.00
All other items approximately the same as above estimate for sulphite mill	15,775.00
	24,775.00
Plus 15 per cent for erection	3,716.25
	28,491.25
Power required, 200 horsepower; if this is developed by steam, add	5,000.00

This estimate would be reduced still further by substituting winnowing or glass-cleaning machinery for the expensive items of wood-preparing machinery, knotter, etc., for a mill manufacturing soda pulp from perennial grasses.

There should be added to the above pulp mill estimates for a complete plant for paper making:

One Fourdrinier machine complete	$50,000.00
Building, capital, etc.	50,000.00
Miscellaneous paper making machinery, not included in pulp mill equipment, including refining engines, cutters, calenders, dryers, molds, presses, etc	20,000.00
	120,000.00

The following is a summary:

A 10-ton sulphite wood pulp and paper plant complete	$163,841.25
A 10-ton soda wood pulp and paper plant complete	153,491.25
A 10-ton soda pulp and paper plant for manufacture of grass, straw and bamboo paper	140,000.00

GENERAL CONCLUSIONS.

Although the process of paper making is distinctly technical, yet it can not be said that the industry as a whole is operated on a strictly scientific basis. The establishments which employ trained chemists, men thoroughly grounded in the fundamental principles of the science and able to handle new problems, are comparatively few in number. A man capable of assaying bleach liquor or other chemicals used, is all that is required at the present time. However, I firmly believe that in a comparatively short time the lines of competition in this industry will be so closely drawn that the services of a chemical technologist will be necessary. The capacity of the average analyst employed in paper mills to handle technical problems is limited to work of a routine nature, although this is not always what is expected of him at times when unforseen difficulties arise. The most abstruse investigation may become the source of important practical progress.

We have prepared in this laboratory pulp boards and handlaid bleached and unbleached paper from the various raw materials, treated by both chemical processes, and samples are on hand for distribution to those who may be interested.

ILLUSTRATIONS.

PLATE I.

[Photomicrographs by Martin. Fibers seen longitudinally.]

FIG. 1. Lauan (*Shorea contorta*).
2. Mayapis (*Anisoptera vidaliana*).
3. Cupang (*Parkia roxburgii*).
4. Dita (*Alstonia scholaris*).

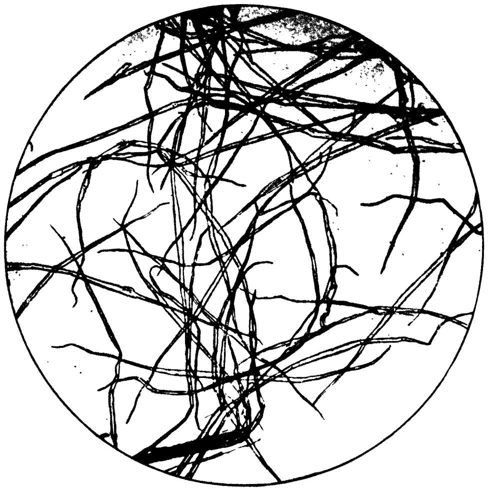

FIG. 1.

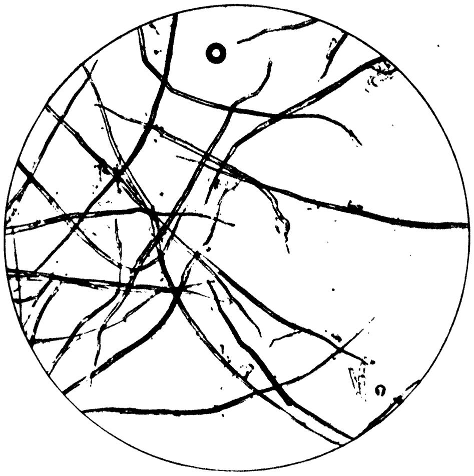

FIG. 2.

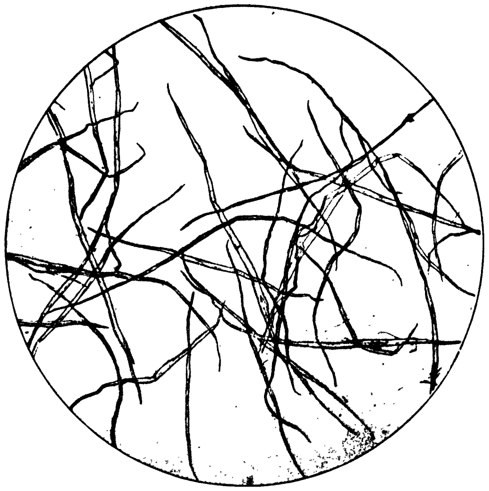

FIG. 3.

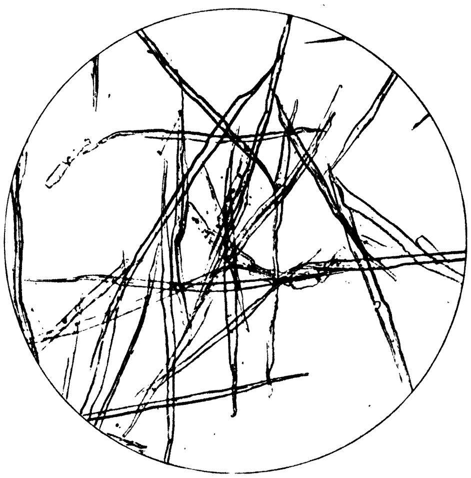

FIG. 4.

PLATE I.

THE CRATER LAKES OF TAAL VOLCANO.

By Raymond Foss Bacon.

(*From the Chemical Laboratory, Bureau of Science, Manila, P. I.*)

About a year ago I published the results of analyses made on the nature of the interesting lakes in the crater of Taal volcano.[1] The water examined at that time was brought to the laboratory in January, 1906. Another expedition from this laboratory visited the volcano early in March, 1907, and it is the purpose of this paper to record the data then collected. During the intervening period no marked eruptions of the volcano had occurred, but it was nevertheless found that quite evident changes had taken place in the crater area; these are shown by a comparison of the photographs taken two years ago, one year ago and recently. (See Pls. II to VI.) The yellow lake, which existed in 1906 and of the water of which an analysis was given in the former communication, has entirely disappeared; even the lake bottom had been completely filled up so that there now is nothing to indicate that such a lake ever existed. Other places where small, red and green lakes were seen by the previous expedition, were also dry, although in most cases the lake beds were still sharply defined, the former bottom was covered with a thin, red or yellow crust which would not support a man, the stratum underneath being a soft, wet mud. The green lake has diminished in area, so that now access is possible to the two fumaroles at its south end; these are each about 10 meters in diameter at the surface, sloping conically to an opening into the earth of about 0.5 meter. From one of these blowholes a very large amount of steam not under great pressure is continually rising; from the other, much hot gas containing a large quantity of sulphur dioxide is issuing under considerable pressure and with a deafening, roaring noise. (See Pl. VI, fig. 3.) The two vents, which are not more than 15 meters apart, are evidently independent and not connected at any place near the surface.

To the southeast of the green lake, a basin is found in the present active crater, surrounded on three sides by high, perpendicular, rock walls, the least distance to the surface of the water being about 30 meters. The water of this lake is in constant, violent ebullition and great masses of steam and sulphur dioxide are continually rising from its surface, so that it is only possible to see it when a favorable wind blows the steam to one side; the water is covered with a greenish scum which is continually broken by the bubbles of steam and gas rising through it. The walls surrounding this crater lake are covered with an efflorescent deposit which is white, red, yellow, blue, and green in color and which is most probably not due to salts sublimed or distilled up on the rock walls from the boiling, acid lake below, it being formed by the action of the hot acid vapors on the lavas constituting the walls. That this is the case is shown by the fact that the colors of this deposit are stratified in a manner corresponding to the layers of lava. (See Pl. IV, fig. 2.) Sublimation would not in all probability have given such a stratification. This efflorescence consists of iron, aluminium and magnesium sulphates and chlorides and just as is the case with the water, aluminium is the predominant metal, iron coming next, and magnesium being present in moderate amount. In many specimens of this efflorescence the acid radicals have been lost, so that the residue is largely changed to hematites and clays. Oebbeke[2] in discussing the rocks from Taal speaks of the large number of feldspars and other aluminous rocks which he found in the neighborhood of the volcano, and gives the following analysis of the massive rock from Taal volcano:

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[1] *This Journal* I, 433.

Analysis of massive rock from Taal volcano according to Oebbeke.

SiO_2	58.42
Al_2O_3	17.64
Fe_2O_3	5.66
FeO	4.00
MnO	.48
CaO	4.50
MgO	2.54
Na_2O	4.44
K_2O	2.52
H_2O	.42
TiO_2	.31
	100.93

Mr. W. D. Smith of the Division of Mines of this Bureau tells me that he has examined rocks from Taal volcano and its immediate neighborhood, which contained large amounts of many classes of feldspars. These facts are mentioned as suggesting the source of the great quantity of aluminium salts and of alumina noted in the waters and in the effervescent deposits.

From a chemical point of view the striking aspect of the volcano consists in the large amount of salts of iron which are visible on all sides; the rocks being to a great extent colored to a red or yellow owing to the deposition of components of iron salts showing such coloration; the deposits are to be found all over the volcanic island. We were unable to discover any sulphur in the crater of the volcano, although very perfect gypsum and alum crystals, colored to a sulphur yellow by salts of iron, were everywhere vigorously growing within the crater. Small fumaroles and fissures in the ground are situated all over the crater areas, even on the highest points on the walls; these emit steam and hot, sulphurous gases. The same class of efflorescent salt deposit as is encountered on the walls surrounding the boiling crater lake is encountered around the openings of many of these small vents. In examining these fumaroles it was noted that steam issued from some, whereas others gave off hot, sulphurous gases. No hydrogen sulphide was detected in the gases issuing from the various fumaroles in and around the crater, and the absence of any deposits of sulphur in the crater would suggest that this gas is never present, because, in the presence of the large amounts of sulphur dioxide, hydrogen sulphide, were it at any time a constituent of the volcanic gases, would certainly be decomposed to form sulphur.

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[2] Beitr. z. Petrographie der Philippinen u. der Palau-Inseln, Stutt. (1881), 27.

Specimens of water were collected as follows: (*a*) From the boiling crater lake (Water No. 1); (*b*) from a green pool immediately to the north of this boiling lake (Water No. 2); and (*c*) from the green lake (Water No. 3).

Water No. 1 is of a light grayish-green color; it is quite full of sediment, due to constant ebullition; its temperature is a little over 100° C.; it is very acid and possesses a strong odor of sulphur dioxide. It was much lighter in color than are the other waters, because sulphur dioxide is continually bubbling through the lake from which it comes, thus keeping the iron salts in almost a colorless, ferrous condition.

Water No. 2 is of a deep green color. It was collected from one of a series of remarkable and formerly inaccessible pools which are found in what at first sight appears to be a filled-in extension of the boiling crater lake. What seems to be the northern beach of this lake consists of a crust of various colored iron and aluminium salts, in which numerous, small pools, 0.5 to 5 meters in diameter are encountered. These pools are of different colors—yellow, blue, green, and deep red. Some are boiling and are continually sending out small clouds of steam, while others in the immediate neighborhood are relatively cold. The one which was accessible, and from which the water which I analyzed was obtained, is boiling hot. The crust between these lakes will not support a man, hot water is present beneath it. It is remarkable that these pools should be so different in character, as is evidenced by their different colors and temperatures, when they occur in such close proximity to each other, with only apparently a thin, soft crust separating them. In fact, I was surprised to find the water of the pool which I examined to differ from the waters of the crater lake proper, as the formation appears as if it were merely a part of the crater lake which had been filled in with colored salts through which the water still reached the surface in the remaining pools. This curious and beautiful formation is shown by Plate V, fig. 3, and Plate VI, fig. 2.

Water No. 3, from the green lake, is of a very deep, green color, it has a very strong, acid taste and, as obtained, it contained considerable sediment. However, farther from the shore the water is clearer. The sediment is largely clay and gypsum. All around the edges of this lake and covering the bottom near the shore, is a very abundant growth of gypsum crystals; the ones on the shores of the lake being colored yellow by iron salts.

Qualitative analyses demonstrated that all three waters contained the same elements, ferric and ferrous iron, aluminium, magnesium, calcium, strontium, barium (spectroscope), ammonium (small amount only), potassium, sodium, sulphuric and hydrochloric acids, and phosphoric acid (traces). No cæsium or rubidium or other rare or unusual elements could be detected by spectroscopic examination. The quantitative analyses are as follows:

TABLE No. 1.—*Quantitative analyses of water from the crater of Taal volcano.*

[Figures express grams per 100 cubic centimeters of the water.]

	No. 1.	No. 2.	No. 3.
Color	Light grayish green.	Green.	Green.
Sp. gr. at 15°	1.072	1.081	1.158
Acidity	1.33 N.	1.335 N.	1.78 N.
Acidity calc. as H_2SO_4	6.52%	6.54%	8.72%
Calc. as HCl	4.84%	4.87%	6.49%
Total solids (filtered water) by heating to 110° for six hours	8.576	10.1402	19.788
	Per cent.	Per cent.	Per cent.
Chlorine, Cl	4.7512	4.8925	10.9312
Sulphuric ions, SO''_4	3.0808	1.9688	2.3542
Ferrous iron, $\ddot{\mathrm{Fe}}$	.5148	.8367	1.1960
Ferric iron, $\dddot{\mathrm{Fe}}$	.0009	.0843	.1486
Total iron	.5157	.9210	1.3446
Aluminium, Al	.7622	.8978	2.0927
Calcium, Ca	.2813	.2082	.1328
Magnesium, Mg	.0318	.4343	.1514
Sodium, Na	.7419	.7192	2.3246
Potassium, K	.0125	.0048	.0104
Loss on evaporating to total solids	2.1171	.8284	.8985

The "acidity" of these waters, as was that of the waters analyzed a year ago, was determined by titrating with $\frac{N}{10}$ alkali, using phenolphthaleïn as an indicator, and hence it does not represent the true acid value or even the extent of hydrolysis of salts taking place in these waters. This will readily be seen if their composition is only casually considered. These lakes are largely solutions of aluminium and iron chlorides and sulphates. The determinations of the different elements were made directly, both in the present analyses and in the former ones, as it is evident that where iron and aluminium chlorides are present in such large quantities, analyses of the solid residues would not give the true composition of the waters; it is also evident that the total solids obtained by drying for six hours at 110° only approximately represent the quantities of salts originally present, for a solid residue obtained in this way can not give true values, because it is impossible to obtain constant weight unless the dish is heated for a sufficient length of time to drive off most of the combined chlorine, in which case iron and aluminium will also be lost.[3]

If one calculates the number of anion and kation forming elements from the analyses, some rather interesting and what at first appear to be rather surprising results, are obtained. In Water No. 1 the number of anions largely exceeds that of the kations and this would be expected, as sulphur dioxide is continually bubbling through the boiling crater lake. In Waters Nos. 2 and 3, as well as in the two which I examined last year, the number of kations exceeds the number of anions, but that this condition should exist and the waters still be very acid, seems to be contradictory. However, if the behavior of solutions of aluminium and iron chlorides on evaporation are considered, then the behavior of these waters at once becomes clear.

It is well-known that the so-called neutral salts of aluminium are very acid, acting on metallic iron or zinc just as do dilute acids; the salts of aluminium easily dissolve alumina to form basic salts[4] and from such salts, aluminium oxide and the various hydroxides are only gradually precipitated, the rate depending upon the concentration of acid present, the temperature and other factors.[5] The conclusion is therefore valid that basic salts of aluminium and iron are present in these waters, which are capable of sufficient hydrolysis to give hydrogen ions. It is hardly necessary to state that all determinations have been made in duplicate. The precipitation of alumina from such basic salts must take place with comparative slowness, for it was found that the salts in these waters were not yet in dynamic equilibrium. The filtered samples, analyzed a little over a year ago, have stood in the laboratory in tightly closed bottles. The temperature of Manila varies only a few degrees during the year and in the laboratory one could safely state that the variation of temperature to which these bottled waters have been subjected has not been over 10° C. Nevertheless, a large amount of sediment, which was found to consist of aluminium hydrate and a little gypsum, had collected in each of the containers, and 3 liters of carefully filtered Water No. 3, left standing for one week in a tightly closed, glass-stoppered bottle, had deposited nearly 1 gram of sediment which also consisted of gypsum and aluminium hydrate.[6]

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[3] It would be possible to determine the real amounts of free acid in these waters by a study of the electrical conductivity of these waters as well as of their constituent salts, obtaining the speed of migration of the various ions according to the methods developed by Bredig. Such a determination could also be made by a study of the hydrolysis of esters or of cane sugar.

Such a study would involve very many factors, and would consume so much time, that for the purpose of the present paper it was not considered advisable.

[4] Dammer: Handbuch der anorganischen Chemie (1893), **3**, 91.

[5] Tomasi: *Bl. Soc. chim.* (Paris) (1882), (2) **37**, 443.

Very extensive deposits of a fine quality of kaolin are found in the immediate neighborhood of Taal volcano, near Los Baños and between Mount Maquiling and Taal Lake. It is suggested that these were probably deposited as a result of the disintegration of feldspars and other aluminous minerals by hot, volcanic waters, just as the Taal waters are now depositing compounds of aluminium.

The aluminium, magnesium, calcium, and iron in the Taal waters can readily be accounted for as a result of the action of acid waters on the feldspar rocks in the immediate neighborhood and the nature of the efflorescent deposits found on rocks around the crater lake and the various fumaroles makes such an assumption probable. It is at first difficult to imagine that the large quantity of chlorine could have had its source in anything but common salt, but the amount of sodium present in the waters is sufficient to combine only with approximately 0.2 to 0.33 of the chlorine, so that if the latter element really originated from sodium chloride, much of the sodium must have been taken up to displace other elements in the passage of the water through the rocks. Calcium seems the most probable element to have been so displaced, as gypsum crystals are growing very vigorously both in and around the lakes, and it is well known that an alkali metal, or a metal of the group of alkaline earths, can readily be displaced by another metal of one of these groups, the direction of the reaction depending upon the concentration of the elements in the surrounding waters and taking place according to the general laws of mass action.[7] Rümpler[8] was able to displace calcium by the alkali metals, on filtering sugar saps through various silicates, and he proved that the reaction was one which was readily reversible, its direction depending upon the concentration of the alkali metal and metal of the group of alkaline earths present in the solution. Nothing but the high chlorine content suggests the sea as a probable origin of the waters of the crater lakes of Taal. The volcano is quite near the sea, but the most eminent geologists incline to the view point that volcanic waters do not usually come from that source.[9]

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[6] The extensive French deposits of bauxite are ascribed by Coquard and Angi to hot, mineral springs and geysers which dissolved the alumina and brought it to the surface. Hays ascribes the Georgia, Alabama, and the Arkansas deposits to the action of waters containing sulphuric acid, on aluminous shales and feldspars, the waters probably being neutralized by limestone after reaching the surface.

[7] Van Hise: A Treatise on Metamorphism. *Monograph U. S. Geol. Survey* (1904), 252.

[8] Rümpler: *Ztschr. Ver. Rübenzuck. Ind.* (1903), 798.

It seems most improbable, therefore, to judge from the composition of the waters, that they originate in the sea, and it seems almost equally improbable that the chlorine is due to sodium chloride without making unproved assumptions, and consequently it is more rational to assume that these waters have come from the original magma of the volcanic core, for ferrous chloride occurs in meteorites, for example such as lawrencite,[10] a mineral which is easily decomposed.

THE RELATIVE ABUNDANCE OF THE CHEMICAL ELEMENTS.

Clarke [11] says:

> The resemblance between meteoric stones and volcanic rocks is noteworthy. * * * The earth below its crust may be like a huge meteorite in composition, with the stony part predominating.

He calculates as the average percentage amount in the earth's crust of the principle elements mentioned here as follows:

Chlorine	0.01
Magnesium	2.68
Iron	5.46
Sodium	2.36
Aluminium	7.81
Potassium	2.40
Sulphur	.03
Calcium	3.77

While the average amounts of chlorine and sulphur found in the earth's crust are very small, still it is well known that various elements are often concentrated in limited areas, as in the known cases of mineral deposits. Hence the fact that so small a percentage of chlorine and sulphur are found in the earth's crust as a whole does not invalidate the conclusion that these elements may have originated in the volcanic magmas at this point.

Van Hise makes the following statement:

> If at the time the earth stuff segregated, chlorine was contributed as laurencite, it is certain that the action of waters in the magmas upon this compound would produce hydrochloric acid; this suggests a source of a part of the hydrochloric acid of volcanos.

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[9] Chamberlin and Salisbury: Geology (1904) **1**, 572.

[10] Van Hise: Metamorphism, 978.

[11] Bull U. S. Geo. Sur. **78**, 39.

He further says, concerning the origin of the various elements and compounds found in volcanos:

> The belt of weathering may be permeated locally with hot, gaseous solutions. The work of these gaseous solutions is of essentially the same nature as ordinary gaseous solutions, * * * but the gaseous solutions adjacent to igneous rocks usually contain a greater quantity of the active chemical agents than do ordinary solutions, and moreover their temperature is much higher than normal. This gives a combination which results in much more rapid alteration than the average of the belt of weathering, and alteration of a different kind * * *. It is to be presumed that the ultimate source of the various products found in the belt of weathering is the material of the original magmas. * * * Chlorine, hydrochloric acid, hydrofluoric acid and hydrosulphuric acid are undoubtedly largely formed by the action of hot water upon chlorides, fluorides and sulphides. Sulphurous and sulphuric oxides are produced by the action of the oxygen upon the sulphides.

Van Hise inclines to the view that the volcanic waters as well as the substances dissolved in them usually have their origin in the original magmas and he calls particular attention[12] to the kaolinization of feldspars by wet steam. This possible origin of the kaolin beds must be considered when we wish to arrive at conclusions regarding the origin of the extensive clay beds found in this active volcanic region. These speculations in regard to the origin of the substances found in the crater waters of Taal volcano are of interest, but naturally they can not be conclusive until much more extended investigations, which the Division of Mines of this Bureau plans soon to take up, have been completed. The very exceptional composition of these waters is made more evident by a search through the published reports of water analyses, for I have been unable to find any waters which even approach to them in composition. Many mine waters are markedly acid, but this is usually due to ferrous or other sulphates, which are ultimately referable to the decomposition of sulphides. I have been unable to find reported analyses of waters containing large amounts of aluminium, iron, and chlorine.

A STUDY OF THE RADIO-ACTIVITY OF THE WATERS OF TAAL VOLCANO.

In my first paper on the Taal waters from the crater of Taal volcano, I gave the results of experiments which were all negative, to determine whether these waters are radio-active, but as these determinations were made about one month after the waters were collected they could not be considered as being conclusive. I was especially anxious to test these waters for radio-activity because of the recent theories which have been developed by Rutherford, Strutt and others in regard to the influence which the small amount of radium found in the earth's crust would have on the maintenance of the heat supply, and consequently I considered it of importance to study a hot, active volcanic area in regard to its radium content. Since the first paper was published, Major Dutton[13] has advocated a theory that there is a causal connection between radioactivity and volcanos. A volcano is located in a part of the earth where, for some reason, radium compounds are concentrated, and he believes that the radium salts are the ultimate source of the volcano's heat supply. His arguments in favor of this theory are briefly as follows:

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[12] Loc. cit. 493.

1. The solidity of the earth does not exactly correspond with other theories.
2. The comparative smallness of the extravasated masses in any single eruption is in favor of his view.
3. The repetitive nature of volcanic eruptions favors his contention. Why does not a volcano discharge all the material in one stupendous belch, and then close forever?
4. There is a growing mass of strong and highly concordant evidence showing that the seat of the reservoir is very shallow, it seldom being more than three miles in depth; the indications being that most of the volcanic eruptions originate at depths of between one to two and one-half miles. The evidence of this fact is furnished by the earthquakes which almost always accompany such eruptions.

We may now proceed to state the probable cause of volcanic eruptions. They are caused I conceive by a development of heat, resulting from radio-activity in limited tracts at a depth of 1 to 3—at the very utmost not over 4—miles from the surface, which is sometimes sufficient to melt the rocks affected by it. The melting is gradual, and when a sufficient quantity is melted, the water which it contains becomes explosive and usually suffices to break through the covering, constituting an eruption. When all the lava is erupted and the reservoir is exhausted it closes up for a time. If the heat continues to be generated, more lava is melted, and in due time another eruption occurs. The process may be repeated again. It may be repeated hundreds or thousands of times. The volcanic action may continue in the same place for hundreds of thousands or even millions of years, or it may repeat itself only a few times, or may even occur only once.

Rausch von Trauenburg[14] made some observations on the crater of Vesuvius—the gases from which produced marked ionization and a prompt discharge of the leaves of the electroscope.

Loudebeck[15] has answered Major Dutton in so far as the geologic phases of the question are concerned. He shows that the composition of lavas is such as to preclude their having their origin at such slight depths in the earth, for they differ in chemical composition from the major sedimentary rocks, and hence must have originated below the zone of sedimentation.

If a volcano is such a center of radio-activity, a place where radium is so concentrated in the earth's crust that the rocks are melted by the perpetual heat store, then materials collected from a volcanic crater should be exceedingly active. Taal, which is an active crater, offers a good opportunity to test the theory. I have examined the waters collected by this expedition as well as the lavas, efflorescence and sediments. The apparatus used was like that described in the former paper, being an electroscope in a large chamber of the general type of instrument used by Elster and Geitel[16] and by Mache[17] and other European workers in their investigations on the radio-activity of ordinary materials. The normal rate of movement (air leak) of the gold leaf of the electroscope was forty divisions per hour and it was fairly constant over the period of the investigation. The waters were examined according to the methods of Mache,[18] air being sucked through the water, the emanation being drawn with it into the jar containing the electroscope. Waters Nos. 1 and 2 showed no trace of activity. Water No. 3 was slightly active, the gold leaf movement being increased by it to sixty divisions per hour. Barium sulphate precipitates, formed in these waters, were all inactive. In examining solids, 100 grams were generally placed in the jar containing the electroscope, according to the method used by Elster and Geitel[19] in testing clays and other materials. The sediments of waters Nos. 1 and 2 were inactive, that of No. 3 was active, the rate of movement of the gold leaf being increased to two hundred divisions per hour; it was five times the normal. The emanation obtained by decomposing the sediment with hydrofluoric and nitric acids, and then blowing air through this active specimen, fell to half the original value in about four days; this phenomenon corresponds to that exhibited by radium; the excited activity also fell to half value in about thirty minutes, which likewise points to radium as its source. For comparison one gram of uranium oxide (black, Kahlbaum) was placed in the apparatus, the rate of fall of the gold leaf was then one hundred per minute, or six thounsand per hour. One gram of pitchblende from Joachimthal, containing 26.1 per cent of uranium, gave a rate of twelve thousand five hundred per hour, a magnitude which is about six times the rate per unit for uranium from the natural mineral, as compared with that from the chemical oxide. This rate agrees very well with that found by McCoy[20] as the ratio between a natural (uranium containing mineral) and a pure uranium salt.

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[13] *Journ. of Geol.* (1906), **14**, 259.

[14] Quoted by Dutton, *loc. cit.* Castovina (*Boll. Accad. Gioenia di Sc. nat. Catania* (1906) **84**, found rocks from Aetna slightly radio-active, the lavas the least so, the soil from the mountain slopes much more active.

[15] *Journ. of Geol.* (1906), **14**, 747.

Boltwood's determination of the amount of radium per gram of uranium in any natural mineral is 8×10^{-7} grams. The sediment which I found to be active could then contain only 4.3×10^{-11} gram of radium, a quantity which corresponds to 4.3×10^{-13} gram of radium per gram of sediment.

Strutt[21] made tests on various igneous rocks from different parts of the world and found them all to show radio-activity, the most active being the more acid granites and syenites, the least active, basalts and various ultra basic rocks. The range in content is calculated at from 1.84×10^{-12} to 25.5×10^{-12} gram of radium per cubic centimeter of rock, or 0.613×10^{-12} to 9.5×10^{-12} gram of radium per gram of rock. Rutherford calculated that samples of soil examined by Elster and Geitel in Berlin contained 10^{-13} gram of radium per gram of soil.

[16] *Physikal, Zt. schr.* (1904) **5**, 321.
[17] *Monatsh. f. chem.* (1905) **26**, 595.
[18] *loc. cit.*
[19] *Loc. cit.*
[20] *Ber. d. chem. Ges.* (1904) **37**, 2641.
[21] *Proc. Roy. Soc. Lond. Sec. A.* (1906) **77**, 472.

It will be seen from the above that the sediment from water No. 3 is only very feebly radio-active, for it increases the natural air leak to only five times the normal rate. It is not at all uncommon to encounter clays and solids which increase it from fifty to one hundred times, in fact Elster and Geitel[22] found a comparatively immense amount of radium in the so-called "fango," a fine mud from hot springs in Battaglia, northern Italy. Natural carbonic acid obtained at great depths from old, volcanic soil was found to be radio-active by these observers. The famous medicinal hot springs of Europe have all been examined, and most of them have been found to be radio-active, but Curie and Laborde and others have examined hot springs which are not radio-active, so that the phenomenon is not entirely a general one.

I do not attach too great importance to the actual numerical value of the radium content of the sediment as it is calculated above, as the apparatus used was somewhat crude, but the numbers given agree pretty well with those obtained by others using a similar type of apparatus, but certainly the amount of radium in this sediment is extremely small. In fact Strutt, in examining various rocks, often found granites which gave a higher value than the one found by me. Therefore, as so little radioactivity was found in this one specimen, and especially as no trace of such activity existed in the boiling, crater lake, it must be concluded that Taal is a volcano which is not located over an area of a concentrated supply of radium, and that therefore Dutton's theory will certainly not apply to this volcano.

Another fact which argues very strongly against Dutton's view is the following: Radium is always associated with uranium or thorium. If there were enough radium present in a limited area to melt the rocks, this would also necessitate the presence of large amounts of uranium or thorium. Volcanic lavas and ejecta have repeatedly been examined by chemists, the analyses probably including thousands of specimens, and yet no great quantity of uranium or thorium has been encountered in them. If we calculate from the known radium content of pitchblende it becomes evident that if the heat given off by the minute amount of radium which is present were to accumulate to a sufficient extent to melt the rock, the latter would certainly need to be insulated in a much better manner than we have ever been able to obtain in practice, or indeed better than we have any reason to believe is possible within the earth's crust. Furthermore, there is no evidence that would lead us to believe that the radium content of any area could ever rise above that associated with a pure uranium mineral, that is a quantity which for each gram of uranium would represent 8×10^{-7} gram of radium. The amount of radium occuring in a mineral, per ton of uranium, is 0.72 gram, and it has never been found to be more than this, it being probable that an equilibrium exists between uranium and radium with possibly actinium as an intermediate product. This much radium would evolve about 70 gram calories per hour,[23] an amount of heat which with perfect insulation, would require five hundred and forty days to increase the temperature of one ton of substance of specific heat 1, by 1°, but perfect insulation is not conceivable within the earth's crust.

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[22] *Physikal Ztschr.* (1903) 5, 11.

The above calculation is based on the limit value of the heat which would be possible if we were to encounter a volcano of pure uranium, and which would therefore contain the maximum amount of radium which experimental facts at present show to be possible, and the amount of radium actually found in rocks and minerals is but 10^{-4} to 10^{-5} times this quantity.

In addition to these considerations the fact remains that the waters and sediments from the crater of Taal volcano were found to contain almost no radium.

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[23] Rutherford: Radioactivity (1905), 419.

ILLUSTRATIONS.

Plates I, II, and Plate III, fig. 2, and Plate IV, fig. 1, from photographs by Worcester.

Plate III, fig. 1, and Plate IV, fig. 2, from photographs by Freer.

Plates V and VI from photographs by Bacon.

PLATE I.

FIG. 1. View from the eastern shore of Lake Bombom across to Taal Mountain.
2. View of Taal volcano from Lake Bombom, which completely surrounds the mountain.

PLATE II.

FIG. 1. Eruption of Taal volcano of July 5, 1904. Note the position of the boiling lake to the right of the erupting crater.
2. Another phase of the eruption of July 5, 1904. This eruption was characterized by the large amount of mud ejected causing, at its height, a violent mud shower.

PLATE III.

FIG. 1. The same crater in September 1904. The eruption has almost completely died down. The boiling crater lake is shown on the right of the active cone.
2. The same crater on December 31, 1905. Almost all signs of activity have now disappeared and the crater is filled with water.

PLATE IV.

FIG. 1. Panoramic view of the whole crater of Taal volcano on December 31, 1905.
2. View across the boiling crater lake showing the stratified walls surrounding it, and the salt deposits on these walls, December 31, 1905.

PLATE V.

FIG. 1. Panoramic view of the whole crater of Taal Volcano on March 4, 1907. The crater active in the eruption of July 4, 1904, and full of water on December 31, 1905, is now seen to be dry and totally inactive. The boiling crater lake is increased in area, while the green lake has decreased in size. A new disturbance area seems to be breaking out to the left of the boiling crater lake.
2. View looking toward the boiling crater lake. In the foreground are seen some of the small pools referred to as the north beach of this lake.
3. The peculiar formation of colored, boiling pools separated by a crust of iron salts, called the north beach of the boiling crater lake.

PLATE VI.

FIG. 1. View looking down from the north upon the yellow lake, the two fumaroles and the boiling crater lake.
2. Looking down from the north upon the boiling crater lake. In the foreground is seen the peculiar formation of the north beach of this lake.
3. The two fumaroles at the head of the green lake. The yellow lake discussed in the former paper was situated to the left of these fumaroles. It is seen that no trace of it remains.

FIG. 1.

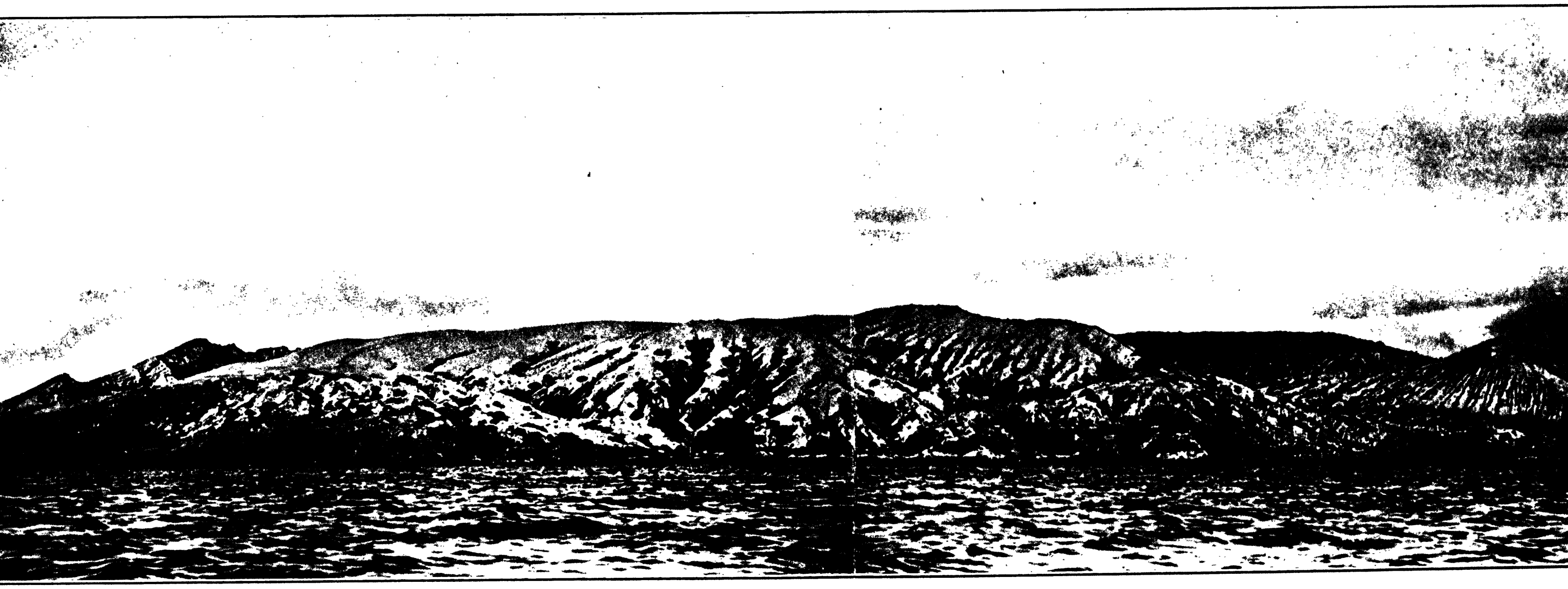


FIG. 2.

PLATE I.

FIG. 1.

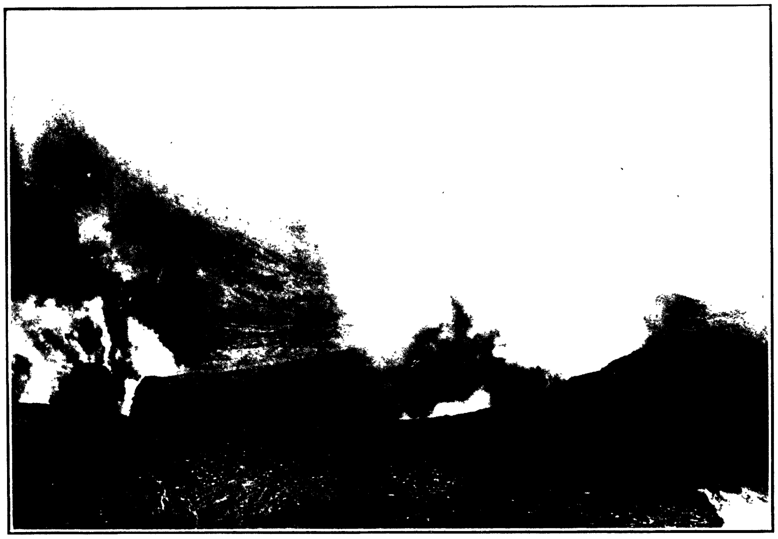
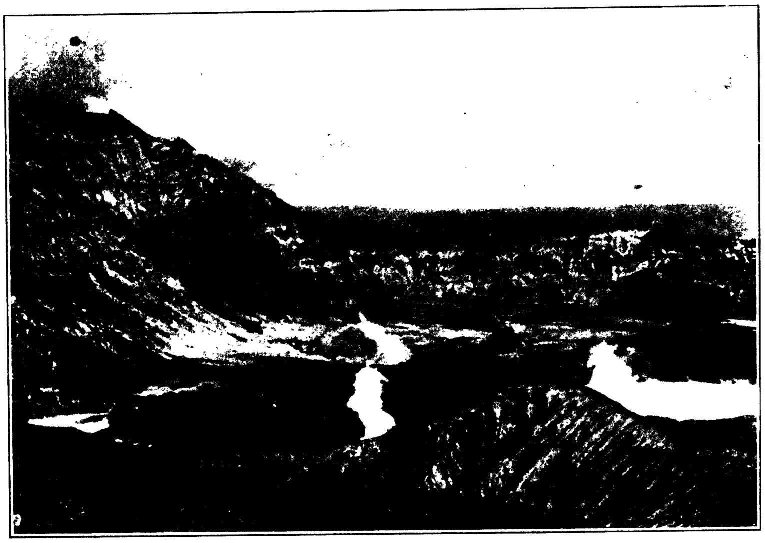


FIG. 2.

PLATE II.



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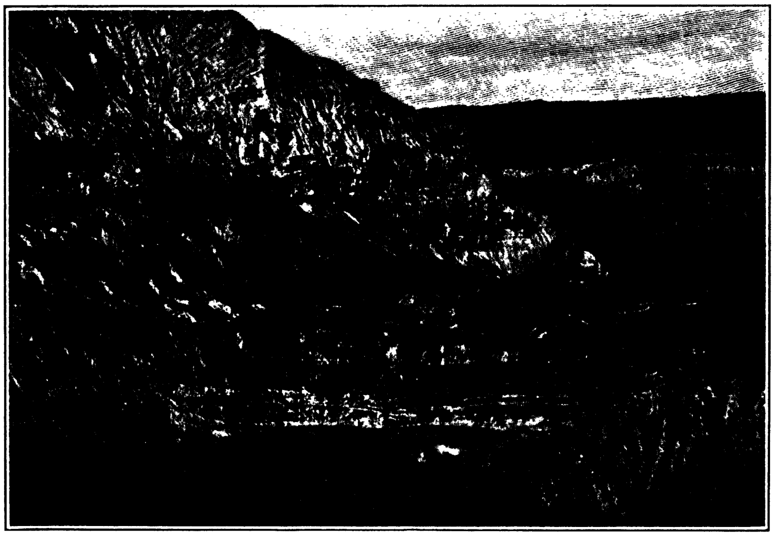
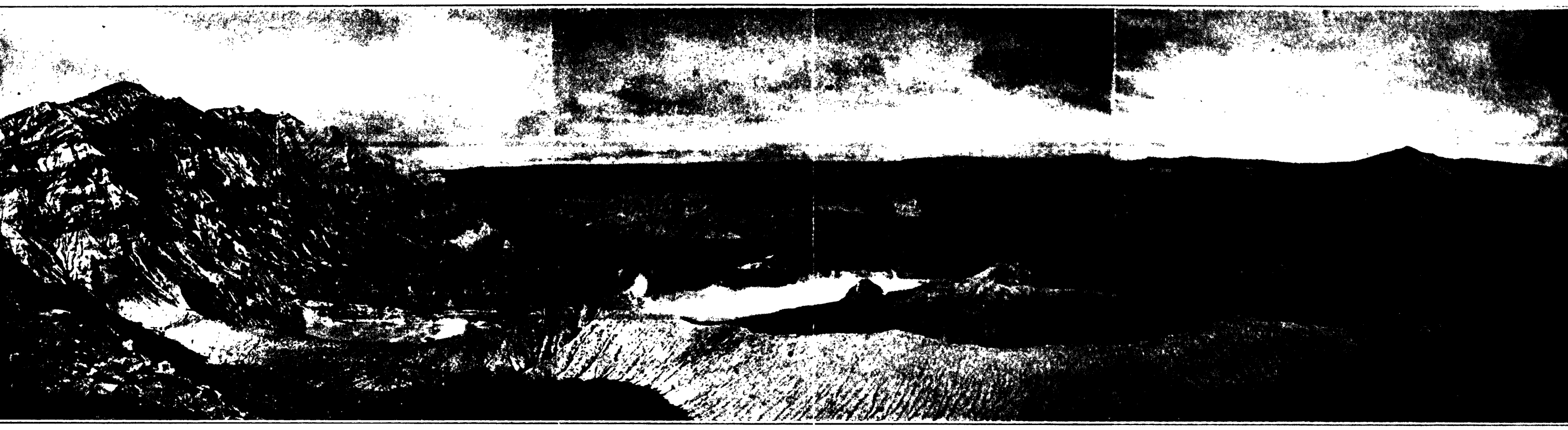


FIG. 2.

PLATE III.



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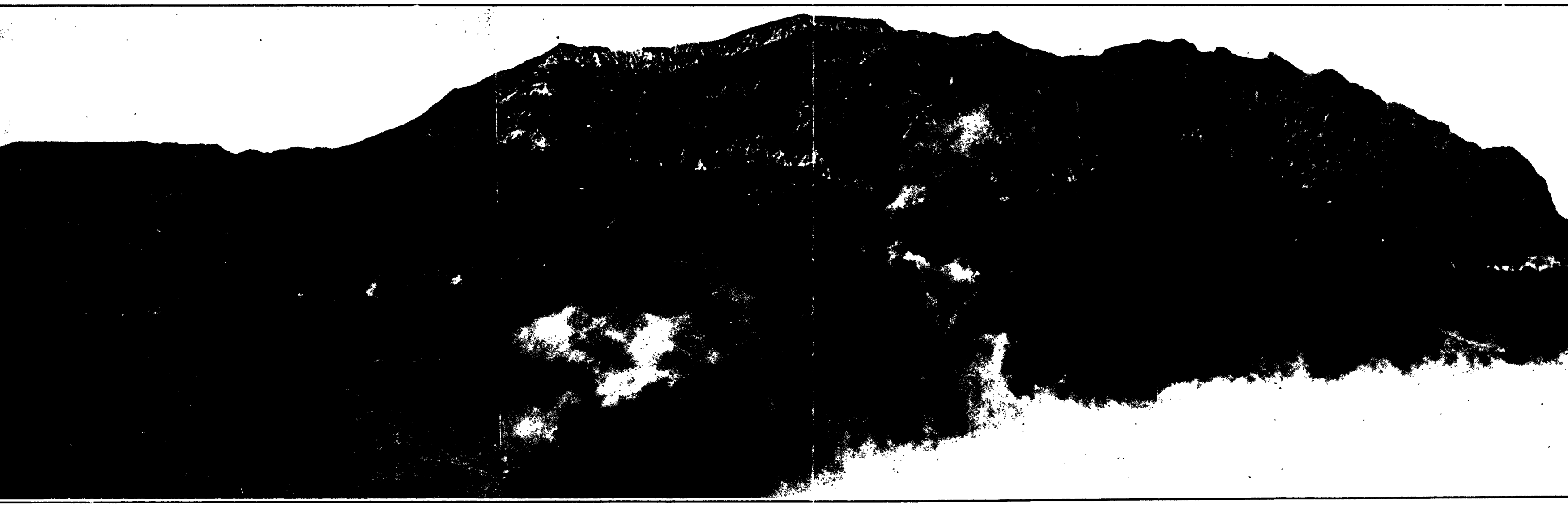
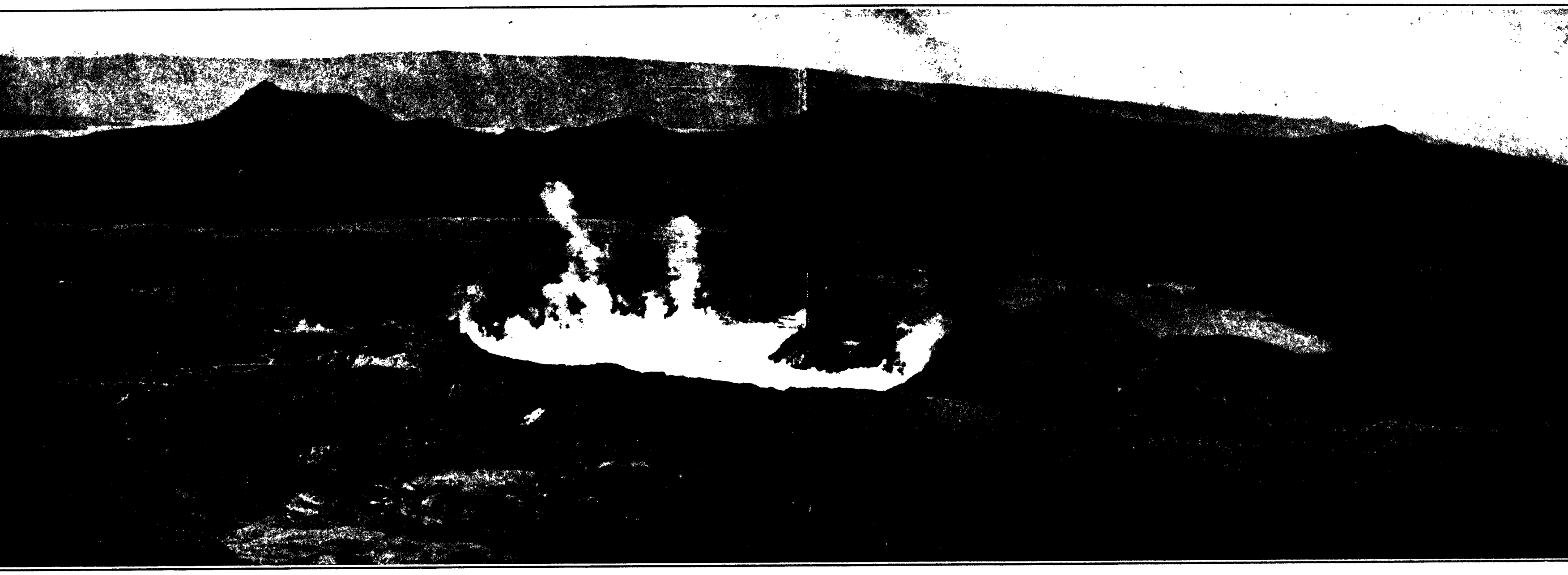


FIG. 2.

PLATE IV.



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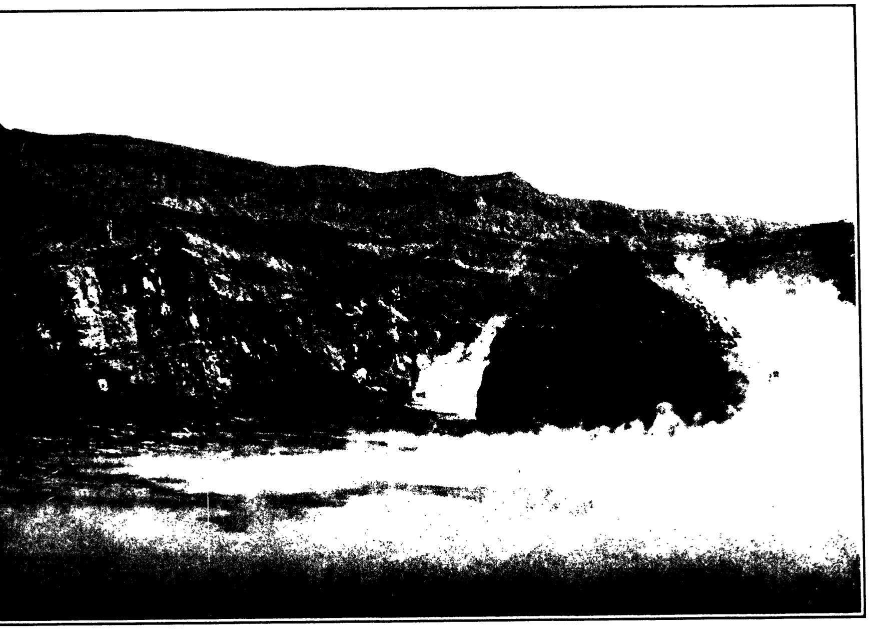

Fig. 2.

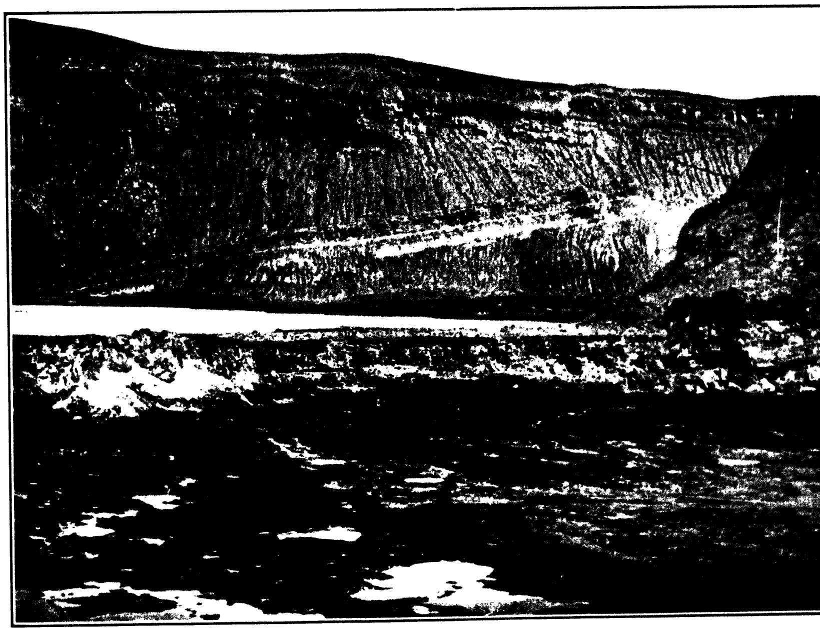

Fig. 3.

PLATE V.

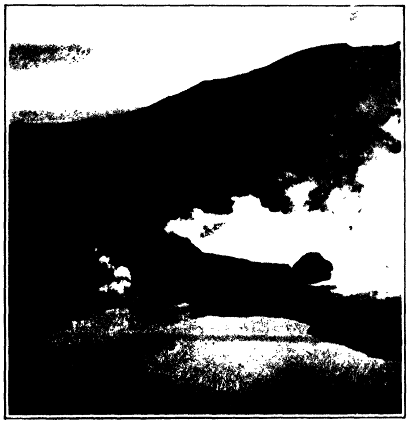

FIG. 1.

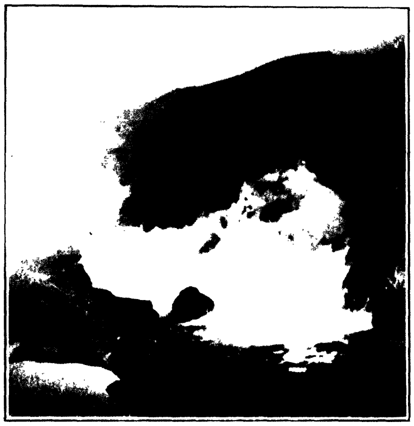

FIG. 2.

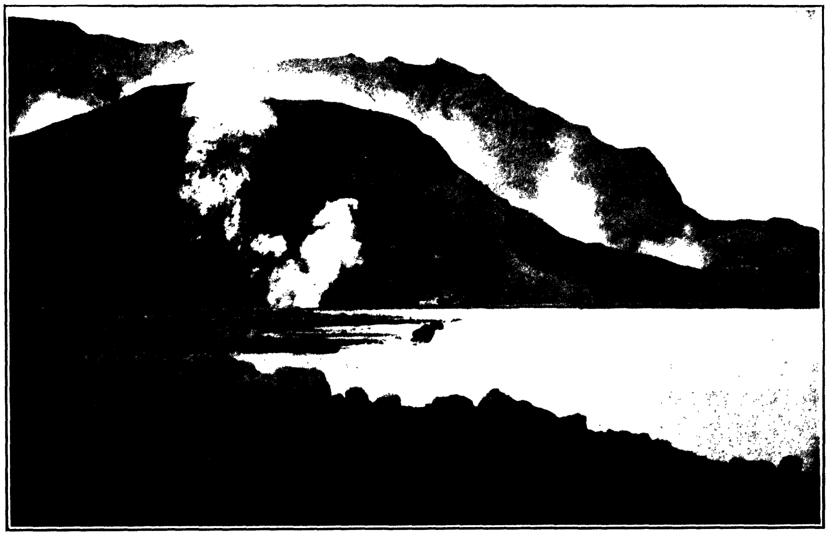

FIG. 3.

PLATE VI.

CATALYSIS BY MEANS OF URANIUM SALTS IN THE SUNLIGHT.

By Raymond Foss Bacon.

(From the Chemical Laboratory, Bureau of Science, Manila, P. I.)

A few experiments were undertaken on the catalyzing effects of uranium salts in sunlight in conjunction with the study of the radio-activity of the waters from Taal volcano, described in the preceding paper. Seekamp[1] a great many years ago demonstrated that uranium salts acted as catalyzers in decomposing oxalic acid in the sunlight, but the same effect was not produced in the dark, even at 100°. The products of the catalysis were carbon monoxide, carbon dioxide, water and formic acid; on substituting succinic acid, Seekamp obtained propionic acid and carbon dioxide. Since the discovery of radium and of its capability of powerfully catalyzing many chemical actions, it becomes interesting to ascertain whether the catalytic action of uranium salts in the sunlight may not be due to the fact that uranium is one of the elements which forms radium and whether its power of catalyzing may not in some manner be connected with its radio-activity. As the sunlight of the Tropics afforded an exceptionally favorable opportunity, the following experiments were undertaken with the view of proving or disproving this supposition.

The apparatus consisted of a 100 cubic centimeter, graduated Ehrlenmeyer flask and a eudiometer. The flask was tightly closed with a well-fitting rubber stopper, through which a glass tube passed to the eudiometer. The gas was collected over the water. Two or more such flasks were usually placed in the sunlight simultaneously, and the time necessary to collect a certain number of cubic centimeters of gas was noted.

The fundamental experiment was instituted to give a comparison of the rate at which a certain quantity of uranium salt would act as a catalyser of oxalic acid, when it was compared with pitchblende containing the same amount of uranium, pitchblende being over five times as radio-active—measured by the electrical method—as the uranium salt. It would follow from this that, if radio-activity had any connection with the catalytic process, the rate of gas formation with pitchblende would be very much more rapid than it would be with uranium salt.

A few experiments were first made in the apparatus with oxalic acid alone, 5 grams being used in each instance, and it was found that sunlight decomposes pure oxalic acid so slowly, as compared with the speed of the reaction with uranium salts, that the autodecomposition may be altogether neglected in the present series of experiments.

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[1] *Am. Chem.* (*Liebig*), (1862) **122,** 113; (1865) **133,** 253.

This result is in accord with those obtained by Richardson[2] who found that oxalic acid is only slowly decomposed by sunlight even at 0°, to form carbon monoxide, carbon dioxide, and hydrogen peroxide. The reaction does not take place under the red rays of the spectrum alone; sterilization has no effect, so that microorganisms take no part in it, although it is known that certain microörganisms decompose oxalic acid under proper conditions, to give carbon monoxide, carbon dioxide and water. No hydrogen peroxide is formed in the dark, even if oxygen is present. Dilute sulphuric acid does not decompose oxalic acid in the absence of light, as was proved by drawing air for seven days through a solution of the acid and into one of barium hydroxide, the oxalic acid being kept at 70° to 80°. Dilute sulphuric acid accelerates the decomposition of oxalic acid in the sunlight, for, in seven days, 0.06 gram of carbon dioxide was obtained from 5 grams of oxalic acid.

The reactions catalyzed by uranium salts are in the great majority of cases well known, taking place with extreme slowness when no catalyzer is present.

Experiment 1.—August 22. Direct sun from 2 to 2.45 p. m. To determine the effect of varying quantities of uranium salts on the speed of the reaction. Quantities in cubic centimeters.

(*a*) 5 grams oxalic acid.
2.2245 grams crystallized uranium acetate (Kahlbaum).
100 cubic centimeters water.
(*b*) 5 grams oxalic acid.
1.1386 grams uranium acetate.
100 cubic centimeters water.

(*a*)	(*b*)
45	40

When placed in diffused light in the laboratory (*a*) gave no more gas (*b*) gave 2 cubic centimeters.

Experiment 2.—August 30. Both flasks (*a*) and (*b*) were left in partial sunlight for fifteen minutes. One cubic centimeter of gas had collected in each one. On placing the flasks in the diffused light of the laboratory, gas continued to be formed for two hours, the amount being 12 cubic centimeters and 7 cubic centimeters, respectively, for (*a*) and (*b*). After placing a solution in the sunlight it takes some time for the reaction to attain its maximum rate, a fact which has often been noted concerning it. An oxalic acid solution containing uranium salts gives no gas, even at 100°, if it is kept in the dark.

Experiment 3.—The solutions (*a*) and (*b*) were the same; the number of cubic centimeters of gas obtained from the two solutions in the same length of time and under the same conditions of sunlight were:

(*a*)	(*b*)
33	28
10	11
17	12
13	10.5
33	28

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[2] *J. Chem. Soc.* (1894) **65**, 451.

It is therefore evident that the relative amounts of uranium salt only slightly affect the speed of the reaction.

Experiment 4.—Two cubic centimeters of concentrated nitric acid added to (*b*). Quantities in cubic centimeters.

(*a*)	(*b*)
32	27
16	11.5

Experiment 5.—Two quantities of solution (*a*) were compared with a solution containing 5 grams of oxalic acid and 2 grams of pitchblende, dissolved in the smallest possible quantity of nitric acid. The solution containing pitchblende (*b*) decomposed the oxalic acid at one half the rate of (*a*).

Experiment 6.—

(*a*) 5 grams oxalic acid.
100 cubic centimeters water.
(*b*) 5 grams oxalic acid.
2 grams thorium nitrate.
100 cubic centimeters water.

In one hour and thirty minutes in sunlight, each gave 0.5 cubic centimeter gas. The thorium nitrate was but slightly dissolved and the solution was very milky in appearance.

Experiment 7.—To each of solutions (*a*) and (*b*) from experiment 6, 5 cubic centimeters of concentrated nitric acid was added partially to dissolve the salt of thorium, the time in sunlight being two hours. Quantities in cubic centimeters.

(*a*)	(*b*)
1.2	14

As the thorium salt is only slightly dissolved, this fact may have rendered the reaction in (*b*) slower than it otherwise would be, but nevertheless it is interesting to note that the radio-active thorium salts catalyze a solution of oxalic acid.

Experiment 8.—It was thought that possibly the increased rate of reaction observed in (*b*), experiment 7, might be ascribed to the action of finely divided particles of thorium nitrate as catalyzers. Hence, two flasks were prepared each containing 5 grams of oxalic acid dissolved in 100 cubic centimeters of water. To one of these freshly precipitated barium sulphate was added; to the other, finely ground silica, but no gas was obtained in either flask, even in the sunlight.

Experiment 9.—October 22, p. m.

(*a*) 4.31 grams pitchblende from Joachimsthal, containing 1.126 grams uranium dissolved in 5 cubic centimeters of concentrated nitric acid.
5 grams oxalic acid.
100 cubic centimeters water.
(*b*) 2 grams uranium acetate containing 1.126 grams uranium.
5 cubic centimeters concentrated nitric acid.
5 grams oxalic acid.
100 cubic centimeters water.

Quantities in cubic centimeters.

Time.	(*a*)	(*b*)
3.25 to 3.40	5.5	0.5
3.40 to 3.55	19.0	1.0

October 23, a. m. The tubes were now placed in the laboratory in diffused light; the next morning at 7.50 the reading was—

(a)	(b)
35.0	6.0

At 8 a. m. they were again placed in the sunlight.

Time.	(a)	(b)
8.00 to 8.20	18	3
8.20 to 8.30	35	12
8.30 to 8.38	12	17
8.38 to 8.45	25	40
8.48 to 8.56	10	31
8.59 to 9.14	25	40
9.16 to 9.30	26	36
9.32 to 9.44	22	38
9.46 to 9.56	22	38
9.59 to 10.12	22	37
10.14 to 10.25	22	36
10.27 to 10.43	22	36
10.45 to 10.59	25	38
11.01 to 11.12	24	38
11.42 to 11.58	25	40

October 23, p. m. The tubes stood in the diffused light of the laboratory from 12.00 to 1.00.

(a)	(b)
8.5	24.5

Therefore (a) in two hundred and forty-five minutes gave 297 cubic centimeters of gas, as compared with 561 cubic centimeters obtained from (b). The solution containing the pitchblende had the greater initial velocity which may possibly be due to the presence of iron salts, because the latter at first markedly catalyze solutions of oxalic acid, as is shown by later experiments given below, but radioactivity would seem to have little or no influence on the rate of the reaction, a conclusion which is confirmed by other experiments of the same character; the solution derived from pitchblende always exhibiting a slower rate than the ones containing uranium salts.

Experiment 10.—October 24, p. m.

(a) 1 gram ferric chloride (sublimed).
5 grams oxalic acid.
100 cubic centimeters water.
(b) 5 grams oxalic acid.
100 cubic centimeters water.
Picric acid added sufficient to give a color as nearly as possible like that of the uranium acetate solution used in (b), experiment 9.

Time.	(a)	(b)
1.25 to 2.15	40	0.5
2.26 to 3.20	40	0.5

The next morning the two tubes were place in sunlight at 8.00 a. m.

	(a)	(b)
At noon	2	0.7

This result is characteristic of iron salts when they are used as catalyzers in decomposing solutions of oxalic acid; at first the reaction proceeds quite rapidly, but it becomes slower until finally it is almost imperceptible.

Solution (*b*) was colored as given above because it was thought that perhaps the color of the uranium solution might have some connection with the absorption of the energy of the sunlight and consequently with the catalysis. This idea was especially suggested because ferric chloride, which also acts as a catalyzer in this reaction, is likewise yellow. Another solution, colored yellow with aniline yellow (Grübler & Co.) likewise gave negative results.

It was thought that possibly the ionization of the oxalic acid or of the water might be increased in the sunlight, and that this change in conditions might have an effect on the reaction. Nichols and Merritt[3] have recently demonstrated that fluorescent solutions conduct the current better in the sunlight than in the dark. Fluorescent substances absorb light and do not follow Kirchoff's law; nonfluorescent substances do not increase the conductivity in sunlight. The amount of fluorescence and conductivity are proportional to one another. Unfortunately, the original paper is not accessible to me, so that I was not able to follow the experimental methods employed by the authors, but I measured conductivities of boiling uranium solutions in the sunlight and in the dark in the usual Kohlrausch cell. No difference could be detected between the sunlight and darkness. I also studied the speed of hydrolysis of ethyl acetate by water at a boiling temperature in the sunlight and in darkness. No increase in the ionization of water in the sunlight could be detected by this method, nor does sunlight have any effect on the speed of esterification of ethyl acetate from glacial acetic acid and alcohol.

Experiment 10.—p. m.

(*a*) 1 gram ferric chloride sublimed.
5 grams oxalic acid.
100 cubic centimeters water.
(*b*) 2 grams ferric chloride sublimed.
5 grams oxalic acid.
100 cubic centimeters water.

Time.	(*a*)	(*b*)
2.10 to 3.00	13	40
3.02 to 3.25	23	40
3.30 to 3.53	20	33

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[3] *Phys. Rev.* (1905) **19**, 396.

No gas collected when the solutions were left standing over night. Both were heated to 100° in the morning and then placed in the sunlight.

Time.	(*a*)	(*b*)
8.30 to 10.00	0.5	2.0
10.00 to 11.00	.5	5.0

The marked falling off in the catalysis with ferric salts may be connected with the formation of a precipitate of ferrous oxalate which soon appears in the solution.

It would seem probable that the decomposition of oxalic acid takes the course of first evolving carbon dioxide and leaving formic acid and that the latter then breaks down into carbon monoxide and water, but formic acid with uranium acetate as a catalyzer gave no gas. As formic acid can be demonstrated to be present during the catalysis of oxalic acid by uranium salts, its formation is probably due to the reaction:

$$CO+H_2O=HCOOH$$

accelerated by uranium salts as a catalyzer.

The further study of this phase of the reaction is of considerable importance both from a theoretical and a practical standpoint.

Oxalic acid when treated with potassium bichromate, gives off gas even in the dark, but there is no decomposition either in the dark or sunlight with chromic chloride or with copper sulphate.

Experiment 12.—A study of the decomposition of potassium permanganate in the presence of uranium salts was next undertaken with a solution which contained approximately 4 grams of potassium permanganate per liter. (1 cc=0.00697 Fe.)

(*a*) 25 cubic centimeters potassium permanganate solution
(*b*) 25 cubic centimeters potassium permanganate solution and 10 cubic centimeters water.
(*c*) 25 cubic centimeters potassium permanganate solution, 0.1 gram uranium acetate and 10 cubic centimeters water.

The solutions were placed in the sunlight from 11.15 a. m. to 1.05 p. m., then 40 cubic centimeters of ferrous sulphate solution were added to each, by which means all were decolorized, and they were then titrated back with permanganate.

Number of cubic centimeters of permanganate required:

(*a*)	(*b*)	(*c*)
3.2	3.3	3.3

Uranium salts therefore have no effect on this reaction.

It is well known that reactions involving oxidation and reduction are usually very susceptible to catalyzers, and that many substances such as alkaloids, ammonium salts, sugars, etc., act as if they were poisons for the latter; whereas copper and iron salts usually accelerate the rate.[4]

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[4] Young: *J. Am. Chem. Soc.* (1902), **24**, 301.

Some alkaloids also have a similar "poisoning" effect on the decomposition of oxalic acid in the presence of uranium salts in the sunlight.

Experiment 13.—
(*a*) 4 grams oxalic acid.
1 gram uranium acetate.
100 cubic centimeters water.
(*b*) Same as (*a*) but with 0.1 gram of brucin added. Measurements in cubic centimeters.

Time.	(*a*)	(*b*)
a. m. 8.08 to 9.10	47	30
10.22 to 10.45	48	29
10.48 to 11.05	52	35
11.08 to 11.25	54	29
11.28 to 11.42	50	29
11.44 to 12.00	48	26
p. m. 2.55 to 3.25	54	32
3.30 to 4.00	50	25

Brucin oxalate separates as white, crystalline needles when brucin is added to the solution, so that the concentration of the alkaloid was less than was represented by the amount added.

Experiment 14.—The same solution as in experiment 13, excepting that quinine was substituted for brucin in (*b*). Quantities in cubic centimeters.

Time.	(*a*)	(*b*)
a. m. 8.15 to 9.20	71	27
9.24 to 9.50	76	21
9.53 to 10.20	77	20
10.23 to 10.45	68	18
10.48 to 11.10	75	20

Experiment 15.—In this experiment 1 gram atropin was substituted for brucin and a third solution (*c*) had added to it 0.2 gram cinchonin. Quantities in cubic centimeters.

Time.	(*a*)	(*b*)	(*c*)
a. m. 11.25 to 12.00	81	20	13
p. m. 2.20 to 3.50	108	40	14
a. m. 10.40 to 11.20	84	34	12
p. m. 1.00 to 1.40	78	34	12
a. m. 8.00 to 8.45	72	30	10
8.50 to 9.30	81	40	12
9.40 to 10.15	82	33	8
11.25 to 12.00	80	33	7

Experiment 16.—(*a*) Standard solution. (*b*) With 0.1 gram morphine. (*c*) With 0.1 gram strychnine. Quantities in cubic centimeters.

Time.	(*a*)	(*b*)	(*c*)
p. m. 1.15 to 1.37	51	32	32
a. m. 8.30 to 9.30	102	27	34
9.33 to 10.10	103	38	40

I was surprised to discover, as is shown by experiment 1, that the quantity of uranium salt present did not markedly affect the rate of the decomposition of oxalic acid, but it was even more curious to find that the amount of oxalic acid also had relatively little effect.

Experiment 17.—

(*a*) 4 grams oxalic acid.
1.753 grams uranium acetate.
100 cubic centimeters water.
(*b*) 2.5 grams oxalic acid.
1.753 grams uranium acetate.
100 cubic centimeters water.

	Time.	(*a*)	(*b*)
a. m.	9.24 to 10.02	30	20
	10.04 to 10.20	31	27
	10.22 to 10.43	38	35
	10.45 to 11.08	31	30
	11.10 to 11.30 (shady)	21	21
p. m.	1.35 to 2.01	35	29
	2.03 to 2.22	32	32
	2.25 to 2.46	32	30

Quantities in cubic centimeters.

Experiment 18.—

(*a*) 7 grams oxalic acid.
1.753 grams uranium acetate.
100 cubic centimeters water.
(*b*) 2.5 grams oxalic acid and the same amounts of uranium acetate and water as in (*a*).

	Time.	(*a*)	(*b*)
a. m.	9.00 to 9.45	35	25
	9.47 to 10.04	33	29
	10.07 to 10.28	34	30
	10.30 to 10.40	32	24
	10.43 to 11.08	32	24
	11.28 to 11.45	38	32
p. m.	1.32 to 2.00	33	12
	2.03 to 2.25	35	13
	2.27 to 2.50	35	11

There is therefore relatively little difference in the initial rate of the reaction, but as it proceeds, a marked variation begins to be noted.

I have also made few preliminary observations on the action of uranium acetate in the sunlight, on the decomposition of several organic acids. Propionic acid very slowly gives off carbon dioxide, mixed with a combustible gas which is probably ethane, but the amount which I had at my disposition was too small to identify. Wisbar[5] has shown that *n*-butyric acid gives propane and carbon dioxide. Tartaric acid evolves carbon dioxide quite rapidly and among the decomposition products acetaldehyde and pyruvic acid $CH_3.CO.COOH$ were detected, the presence of the latter being determined by obtaining the phenylhydrazone melting at 188°.

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[5] *Ann. Chem.* (*Liebig*) (1891), **262**, 232.

Pyrotartaric acid is also markedly decomposed, carbon dioxide being evolved, and *n*-butyric and isobutyric acids remaining; malic and lactic acids both give carbon dioxide and probably acetaldehyde, but the other products have not yet been determined. It is not unreasonable to suppose that the first decomposition product formed by the action of a uranium salt in the sunlight on malic acid, is lactic acid which is then further broken down to give acetaldehyde and formic acid.

Mandelic acid decomposes vigorously, benzaldehyde and benzoic acid being obtained in considerable quantity, the benzoic acid presumably resulting by oxidation of the benzaldehyde, for benzaldehyde is rapidly changed to benzoic acid by the tropical sun.

In each of two 250 cubic centimeter Ehrlenmeyer flasks 50 grams benzaldehyde was placed. One flask was put in the dark and the other in sunlight for one week; at the end of this time 2.2 grams and 18.5 grams of benzoic acid respectively had been formed.

It is noticeable that the tropical sunlight greatly accelerates the reaction. The same effect has been noted with a very high frequency electric discharge. Citric acid give off carbon dioxide, acetone being detected among the reaction products; trichlorlactic acid easily produces chloral hydrate; malonic acid gives acetic acid; all of the above with the evolution of carbon dioxide; phthalic and cinnamic acids are not acted upon, probably because of their insolubility.

These few experiments demonstrate the powerful catalytic action of uranium salts in sunlight; a solution of a uranium salt could probably be used as a chemical photometer. I consider the action probably to be intimately connected with the fluorescent nature of the solutions of these salts. The observations given above are very incomplete but as researches of greater economic value to the Philippine Islands are more pressing, I have abandoned the work for the present. It is evident that many reactions can be studied to far greater advantage in the Tropics than in the Temperate Zone, so that a new field for tropical investigation is opened.

A NEW COMPARATOR.

By ALVIN J. COX.

(From the Chemical Division, Bureau of Science, Manila, P. I.)

Prof. Dr. Weinstein[1] says that in the construction of a comparator the following things must be taken into consideration: "(1) The external conditions, under which the comparison of the measures is made, (2) the construction of the measuring apparatus (microscope, micrometer), (3) the properties of the bars investigated." With regard to the first and last points, if the bars compared have the same coefficient of expansion, then it is only necessary to examine them at the same temperature. This is not difficult, for the external conditions can be controlled by the isolation of the cathetometer room and the exercise of due care.

There remains the construction of the apparatus to be considered. The demand for a great many provincial and other secondary standards in connection with the initiation of the new Weights and Measures Law of the Philippine Islands has made indispensable to this Bureau an instrument which could be depended upon to give comparisons with the standard meter bar, accurate within a few numbers in the second decimal of a millimeter. A high grade cathetometer similar to many [2] of those especially designed for making eudiometer readings was tried, but found unsatisfactory for our purposes. The one used is described by Gerhardt [3] as—

> A cathetometer with millimeter divisions of one meter length which at 0° is correct to 0.01 millimeter. The vernier permits a reading of 0.1 millimeter. The telescope turns in a plane exactly at right angles to the upright bar and the level upon the top has a sensibility of twenty seconds. For the first adjustment of the instrument there is a circular spirit level on the base. The telescope, etc., are perfectly balanced. The micrometer is so constructed that the possibility of an inclination of the telescope with the adjustment of the micrometer screw is excluded. Both the bar and the travel are perfectly straight, so that there is no turning of the telescope by moving up and down.

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[1] Weinstein: *Deutsche Mechaniker Ztg.* (1899) (Berlin), 28.

[2] Terquem, A.: *Journ. de Phys.* (1883), **12**, 496. Miller, F.: *Ztschr. f. Instrumentenkunde* (1883), **3**, 409. Fues, R.: *Ibid.* (1886), **6**, 153. Wadsworth, F. L. O.: *Am. J. Sc.* (1896), **151**, 41.

[3] Gerhardt, C.: Preisverzeichnis über Chemische Apparate und Gerätschaften (1905), 13th Ed., 119, Bonn.

This instrument is shown in Plate I, fig. 1. It is not sufficiently accurate for the comparison of measures of length, because the adjustment of the level when the telescope is moved from one end of the upright bar to the other is necessary.[4] The range of the telescope is from three to five meters and with a level, the fineness of which is twenty seconds, makes possible an error of nearly a millimeter. This is the best level usually obtainable for this class of instrument, although sometimes one sensitive to fifteen seconds is used.[5] Even this would not be sufficiently accurate.

As a rule the superiority of an apparatus is proportional to its cost and in this case it was discovered that the only instruments made at present which could entirely satisfy our requirements were very expensive and much more complicated than needed. One was therefore constructed after the following plan and I think for a simple apparatus, it has features worthy of note.[6] In it the general method of comparison now employed in nearly all of the most accurate linear measurements is followed; that is, the length to be measured is placed parallel with the standard bar and the images of the linear lines of the two brought successively into the field of the observing microscope and their relative positions determined. In the forms of the cathetometers previously referred to, this has been done by observing the length to be measured in the telescope and at the same time the scale on the long vertical axis.

The new arrangement is shown in Plate I, fig. 2. In this apparatus the short leverage of the sliding parts and the angular displacement of the telescope are obviated. The base and upright travel columns for the crosshead are the base and standards of a Doolittle torsion viscosimeter.[7] The crosshead is supported by wires, passing over two wheels of the same size with a common axis mounted on a frictionless bearing, and exactly counterbalanced by leaded weights. The bars to be compared are suspended from the arch by vertical adjustible screws, in turn horizontally controlled by thumbscrews from the front and back. The lower ends of the bars are held in place by appropriate clamps. The microscope is mounted on a travel on the crosshead. With the horizontal motion of this travel and the vertical movement of the crosshead, freedom is obtained for the microscope over the entire plane bounded by the vertical columns of the apparatus. The microscope itself has a magnification of sixty diameters and a field of one and two-tenths millimeters. A glass plate graduated into millimeters is adjusted in the microscope tube so that a millimeter here is exactly equal to a tenth of a millimeter in the field, that is, these lines divide the field of the microscope into twelve equal divisions as shown in fig. 1. The glass plate serves as a micrometer device; by its means tenths of a millimeter can directly be read and the variations between the two bars observed, as they are successively brought into the field. For the illumination of the bars a small electric light (not shown in the plate) is mounted just in front of their graduated surfaces during the reading. The zero points of the rods are adjusted by the screws at the top and are then quickly paralleled by passing the microscope downward along the edges of the bars and the lower ends brought into focus by adjusting the clamps.

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[4] This may have been partially due to the heat radiated from the operator expanding the side of the bar nearest him.

[5] *Ztschr. f. Instrumentenkunde* (1905), **25**, 16.

[6] Constructed in the workshop of the Bureau of Science, Manila, P. I., by Mr. J. A. Gilkerson, Chief Engineer, Bureau of Science.

[7] Doolittle, O. S.: *J. Am. Chem. Soc.* (1893), **15**, 173; *J. Soc. Chem. Ind.* (1893), **12**, 709. Wiley, H. W.: Principles and Practice of Agricultural Analysis (1897), III, 343, Easton, Pa.

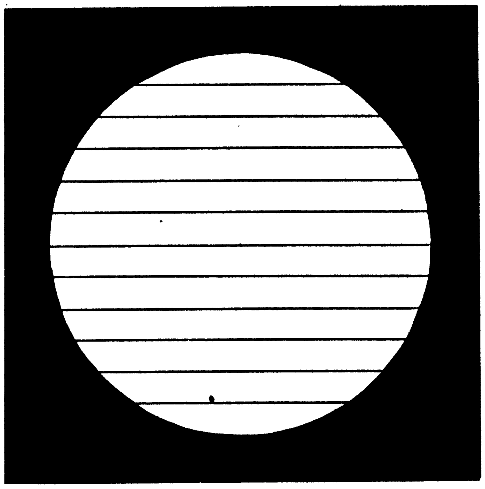

FIG. 1.

This apparatus could be modified to operate satisfactorily in a horizontal position. The reason for making it vertical was to have vertical suspension and avoid the irregularities and inaccuracies produced by sagging or slight bending of the bars; also so that only the upper edge of the microscope travel need be perfectly fitted. At a greater expense an absolutely level table could be constructed for a horizontal apparatus, the microscope travel perfectly adjusted, the whole operated in a thermostat, and therefore the temperature perfectly controlled. With a horizontal apparatus, the adjustments of the bars could possibly be made more quickly.

It is thought that the plan of the double freedom of the microscope possesses many advantages over the stationary microscope and traveling track of other comparators, for example the comparator after Abbe.[8]

[8] *Ztschr. f. Instrumentenkunde* (1892), 12, 311.

With both the vertical and the horizontal apparatus the error of taking the observations is reduced to a minimum, both because of the close range of the microscope and the short displacement between the two bars to be compared. There is practically no liability of disturbing the adjustment while manipulating the microscope. A series of experimental comparisons were made and readings to a hundredth of a millimeter showed no error in the vertical instrument. This apparatus is thoroughly satisfactory for the testing of secondary standards. If it is desired to compare with the greatest accuracy that has yet been obtained, then it is recommended to follow the elaborate and more expensive plan of the Kaiserliche Normal-Aichungs-Kommission.[9]

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[9] *Ztschr. f. Instrumentenkunde* (1895), **15**, 313 and 353.

ILLUSTRATIONS.

PLATE I.

FIG. 1. A cathetometer of standard type.
2. A new comparator.

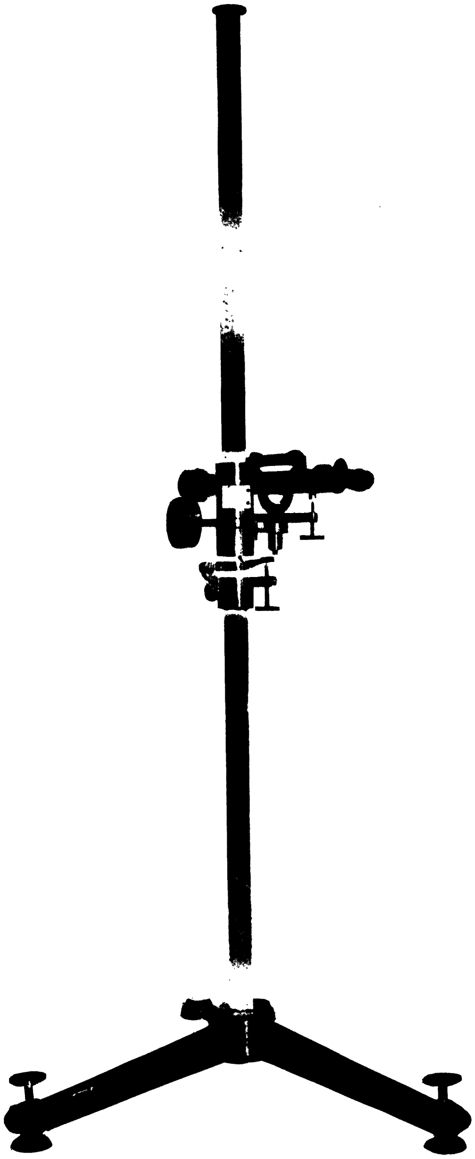

FIG. 1.

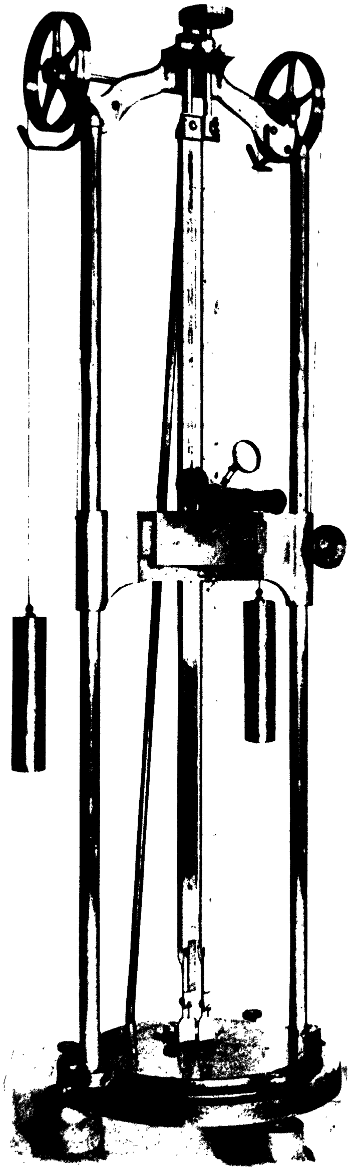

FIG. 2.

PLATE I.

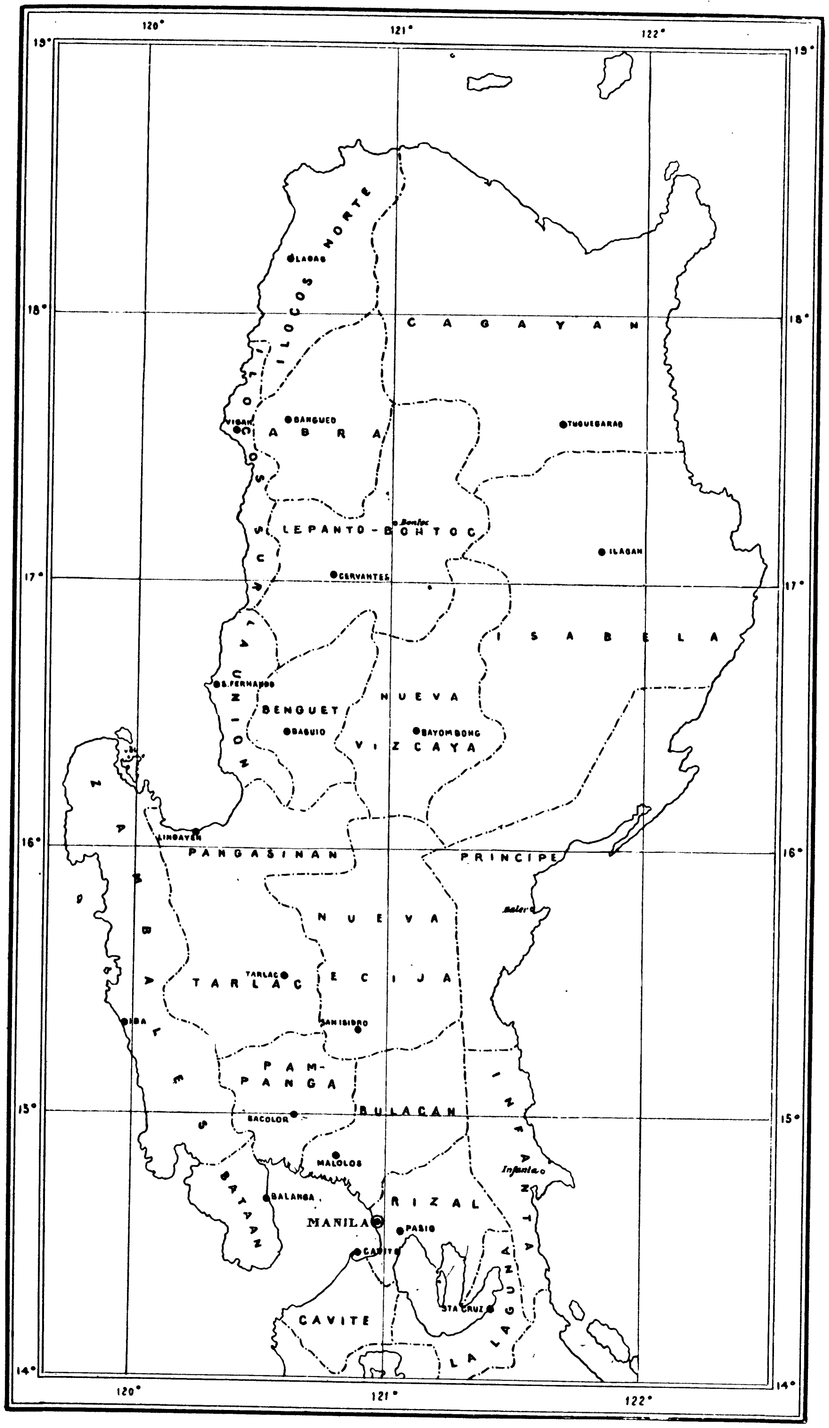
120°
121°
122°
19°
18°
17°
16°
15°
14°
ILOCOS NORTE
LAOAG
CAGAYAN
TUGUEGARAO
VIGAN
BANGUED
ABRA
ILOCOS SUR
Bontoc
LEPANTO-BONTOC
ILAGAN
CERVANTES
ISABELA
LA UNION
S. FERNANDO
BENGUET
BAGUIO
NUEVA VIZCAYA
BAYOMBONG
ZAMBALES
LINGAYEN
PANGASINAN
PRINCIPE
Baler
NUEVA ECIJA
TARLAC
SAN ISIDRO
IBA
PAMPANGA
BULACAN
BACOLOR
INFANTA
Infanta
MALOLOS
BALANGA
BATAAN
RIZAL
MANILA
PASIG
CAVITE
STA. CRUZ
LA LAGUNA
CAVITE

PLATE I.

THE PHILIPPINE

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A. GENERAL SCIENCE

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THE ASBESTOS AND MANGANESE DEPOSITS OF ILOCOS NORTE, WITH NOTES ON THE GEOLOGY OF THE REGION.

By WARREN D. SMITH.

(From the Division of Mines, Bureau of Science.)

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- Correlations.

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- Introduction.
  - Asbestos, manganese, etc.
- Prospecting and development work.
- Transportation.
- Labor.

INTRODUCTION.

Reports to the effect that fairly large deposits of asbestos exist in the northern part of Luzon, have been drifting in from that region for nearly two years.

About a year ago Mr. F. D. Burdette began systematic prospecting and development work in the vicinity of Pasuquin and Nagpartian, and on the receipt of some promising samples from him, the writer was detailed during the month of September, 1906, to make a preliminary reconnaissance of the deposits and of their related geology.

FIELD WORK.

In the absence of proper base maps, there being none even approximately satisfactory save the charts of the Coast and Geodetic Survey, and of course these do not as yet attempt to take in more than a limited area near the coast, I had to be content merely with an inspection of the properties, making limited notes and such sketches of the general geology as were possible.

My first aim was to see all the properties on which development work had been done, afterwards to examine the mere prospects; in the remaining time at my disposal and during the progress of the other work I made such geological exploration as seemed necessary to gain a comprehensive knowledge of the mineral deposits and their relationships.

The schist and serpentine area in the vicinity of the Baruyan and Bamban river valleys occupied the first ten days of the time; my next work lay in the neighborhood of Nagpartian, the hills near by and the coast near Cape Bojeador; I then returned to Pasuquin where I was joined by Mr. Burdette. Together we worked over the country adjacent to Pasuquin and the territory lying between that place and Nagpartian. At no time did we penetrate into the interior for more than 10 miles, for two reasons: First, there has been no prospecting except near the coast; second, at this season of *baguios* or storms, it was found quite impracticable to go any distance from the coast and well-beaten trails; while traveling in this country one is often held up for days and even weeks by swollen streams and flooded fields.

Native horses were used during this work both for riding and packing. When labor was needed, we found the Ilocanos to be very good, although they were not always available nor willing to leave their rice fields. We always found accommodations gladly offered to us by Spanish, English, American, and Filipino residents when near the coast towns, and when in the hills we usually ran into a cazadore's hut.

THE AREA AND PEOPLE.

The Province of Ilocos Norte is a wedge-shaped tract, with the point of the wedge to the south, occupying the extreme northwestern corner of Luzon. It is bounded on the west by the China Sea, on the north by Formosa Straits, on the east by the *Caraballo del Norte* range and the Province of Cagayan, and on the south by the Province of Ilocos Sur and Abra.

The people are called Ilocanos and are Christianized, although some Igorots and Apayáos (Tingianes) inhabit a narrow tract along the slopes of the eastern mountain rim of the province. The Ilocanos have much to commend them, they being in the writer's opinion, together with the Bicols, the most industrious and peaceable native people of the Archipelago. Ilocos Norte, at the time of the census, ranked fifth in amount of live stock; it averaged over 10 kilograms of rice (*palay*—Ilocano name) per hectare, being among the first of the producing provinces; it is least in the number of paupers, and has very few convicts. At the time of the taking of the census the schools were not well under way, but today they are crowded and in a flourishing condition. Rice culture is by far the greatest industry of the province, but the cultivation of maguey, which is said to make nearly as good rope as abacá fiber, is a growing industry.

An interesting feature of many of the towns is the architecture of the churches and towers; the former having strikingly large buttresses; the towers, of which the bell tower in Laoag is typical, are of a distinctly Moorish type, suggesting that the designers came from the Moorish provinces of Spain.

GEOGRAPHY—PHYSICAL.

TOPOGRAPHY.

I shall treat of this topic in three sections as I did in the case of Cebu, dividing the province into three physiographic parts, the *plains*, the *uplands*, and the *cordillera*. Of the last named I shall say practically nothing, as my observations did not extend sufficiently far to the east. Suffice it to say that the great backbone of Luzon, that which runs through the rich mineral Provinces of Benguet and Lepanto-Bontoc, continues high and unconquered almost to the extreme northern point of the Island. Not until a point just east of Bangui is reached is it seen to dip and decline to the sea. At this point there must be a quite precipitous drop of nearly a thousand feet; this can plainly be seen by following the profile. From this drop out to the end of Punta Dialao, the sky line is so very even as strongly to suggest a great marine terrace.

The sky line of the cordillera to the south is ragged and jagged, several peaks standing between 4,000 and 7,000 feet above sea level. It is this great watershed which causes the seasons to be so regularly and sharply defined in this region.

The plains.—Ilocos Norte is fortunately blessed with a fair extent of coastal plain, particularly in its southern part; this varies from 1 to 10 miles in width and is very irregular, for spurs and offshoots from the main mountain mass, in places, run well down to the sea. At about 5 miles from the sea one comes out upon the uplands, and at 17 miles the really high mountains begin; Monte Cayudungan lies just about that distance east of Sinait and it reaches an elevation of 4,816 feet according to Coast and Geodetic triangulation. This plain, as one must reasonably infer from the raised coral reefs along its border, consists of a foundation of extremely recent coral formation overspread by a blanket of silt largely derived from the mountains in the rear; I believe the sediments of this to be to a great extent pluvial; that is, of flood-plain origin and to be *piedmont*[1] deposits, especially where the distance from the foot of the mountains to the sea is considerable; while just bordering upon the littoral they are eolian, there being considerable dune formation along this strip. In this connection I should make mention of the recent articles by Professor Barrell[2] who has emphasized the importance of subaërial and pluvial sedimentation in the geologic record. In the Tropics where we have high mountains and tremendous rainfalls, the conditions are very favorable for the formation of this class of deposits which are very fertile and possess a stiff substratum of clay which is so necessary for rice culture. The Ilocanos inhabit this plain, whereas the Apayaos (Tingians) are confined to the back country. This coastal strip ends near the barrio of Dirique. From there on, around the north coast, there is every indication of very recent vulcanism; in fact, from Bojeador Light running eastward for some miles there occurs a long, black, rugged, treeless ridge of "eruptive conglomerate" which appears to be more recent and quite apart from the rest of the country.

The uplands.—The upland country is not a continuous tract, but is constituted of a series of very irregularly shaped plateaus which approximate 2,000 feet in elevation. These are partly underlain by limestone, partly by dolerite (f. n.); in the former case they are rolling and grassy, in the latter they have more relief and are barren and treeless. Plate III, fig. 2, and Plate IV, fig. 3, will give some idea of this country. The ascent to these higher levels is quite difficult, but the traveler is amply repaid upon arrival by encountering game in abundance. These plateaus are quite different from the upland country of Cebu, but they remind one strongly of the region just around Baguio, Benguet Province.

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[1] Barrell, Jos.: Geological Importance of Sedimentation. *Jour. of Geol.*, U. of C. (1906), 14, 328.

[2] *Ibid.*

The change from one class of country to the other is quite marked and sudden; by crossing a line which is distincly seen to separate them, one goes from a typical, rolling prairie very similar to that of Iowa and Wisconsin in the United States, to a region which, as far as the immediate surroundings are concerned, seems like some of the barren, treeless Coast Range country of California. Great, white patches of magnesite are frequent and the whole landscape appears desiccated and abandoned. These plateau-like uplands may indicate a period of peneplanation prior to the great Miocene uplift which gave the *cordillera* its present height. (Pl. IV, fig. 4.)

There appears to be little or no regularity in the orientation of the drainage in this lower country, for the basal rocks are igneous and are jointed and faulted according to no regular system.

HYDROLOGY.

The principal rivers of this region are the Laoag and the Bacarra, flowing west into the China Sea, and the Bamban northward into Formosa Straits near Bangui. None of these rivers are navigable for large craft, and the Laoag is the only one sufficiently large even for *virays*, the small native canoes. In the rainy season the two rivers first mentioned become torrents and at times they can be crossed only with considerable danger.

In all ordinary weather good anchorage may be found in Bangui Bay during the southwest monsoon. In the season of the northwest monsoon the north coast is out of the question. There are only three of the harbors on the west coast which are used, Dirique, Currimao and Salamague, the last named being the best; all of these are reef-bound and must be entered with great caution. Vessels in skirting Cape Bojeador, usually keep well out to sea, as this is one of the most dangerous points with which the inter-island mariner has to deal.

CLIMATOLOGY.

The climate of Ilocos Norte is considered to be very healthful; it is much cooler than that of most of the coast provinces and its seasons are quite regular. In the time of the northeast monsoon the north coast is very windy and it even may be said to be cold. During this season the town of Laoag, which is the capital of the province, is very pleasant. The word "Laoag" in the Ilocano dialect means "blue skies."

The record of the nearest meteorological station, which is at Vigan, showed the following for the year from January, 1905, to January, 1906:

Record of rainfall, from the meteorological station at Vigan, Ilocos Sur.

	Millimeters.
January	0
February	0
March	22.6
April	10.6
May	22.3
June	693.3
July (missing).	
August	558.1
September	517.5
October (missing).	
November	4.1
December	15.5
Total	1,844.0
Or 72.5 inches.	

The month of September was particularly unfavorable for my visit to this province, but circumstances forced me to go at that time or otherwise indefinitely delay the trip. It might be a matter of interest to state that we experienced three quite severe typhoons during that month, one of these being the one which descended so disastrously upon Hongkong. Fortunately, we were on the outer rim of this cyclone, but even as it was we were afforded an ocular demonstration of what the sea can do along this coast and the necessity of changing ports with the change of monsoons.

One very noteworthy effect of the high seas was the damming and backing of water in the lower courses of the rivers by the high waves, thus greatly increasing the difficulties already attendant upon travel and the transportation of supplies.

GEOLOGY—GENERAL.

IGNEOUS.

Four totally different classes of igneous rock, as follows, were encountered in the region which I covered:

A. Dolerite (f. n.), more precisely speaking a pyroxenite. Basal and plutonic.
B. Granulite—a muscovite granite-intrusive.
C. Andesite—extrusive.
D. "Eruptive conglomerate"—extrusive.

THE PYROXENITE.

This rock is the basal formation, so far as I know, of the region. In some places it is deeply buried, and is to be seen only in deep cuttings in the streams, in others it is exposed on the highlands on the surface where the overlying sedimentary beds have been removed. It is seldom found unaltered, but it occurs in all stages of alteration, from the one showing the mere beginning of chemical change, to a rock wholly serpentine. I first encountered this rock on the summit of the plateau at an altitude of 2,000 feet, northeast of Pasuquin, where it is fairly fresh. The formation is again found near Bangui, and on Monte Inmenso it is little altered, but in many places in the intervening country it is highly serpentinized.

Description.—In the field the rock is black, usually crumbly, and is characterized by innumerable, small veins of magnesite and surface incrustations of the same; it imparts a very dreary aspect to the country where it is the surface rock.

The hand specimen is quite dull, compact and fine grained, however with brighter patches of from 2 to 5 millimeters in diameter, rarely more. These are the rhombic pyroxenes, bronzite and hypersthene, more commonly the former. The luster is due to "schillarization," a well-known characteristic of these minerals in the basic rocks of this type.

Microscopic.—In thin section in ordinary light there are large areas of a yellowish, glassy mineral to be seen, full of cracks and veinlets, forming a mesh structure; occasional irregular sections of a colorless but dirty mineral, marked by very fine and close prismatic cleavage are observed, and finally many irregular patches of magnetite and hematite occur. The first mineral is enstatite, characterized by its low double refraction; the fibrous material in the cracks forming the meshes is serpentine; the large sections with close cleavage and parallel extinction constitute bronzite, in part changed to bastite.

This slide exhibits one of the four characteristic alterations to serpentine. Below is an analysis[3] of this rock:

Analysis.

	Per cent.
SiO_2	37.58
Al_2O_3	.57
Fe_2O_3	9.49
MgO	32.34
CaO	.48
Na_2O	.32
K_2O	.20
$H_2O + 110°$	6.70+100
$H_2O - 100°$	12.64+110
TiO_2	Trace.
P_2O_5	None.
MnO	.28

THE GRANULITE (MUSCOVITE GRANITE).

Up to this time this rock has been encountered only in three localities in this province—at Dalumat, the southernmost point, in the headwaters of Caraon River, and at Baruyen Hill, close to the north coast of Luzon.

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[3] Analysis by L. A. Salinger, Chemical Division, Bureau of Science.

In the first and last localities named it is found in fragments or blocks indefinable from the schists, without any apparent connecttion with any other similar igneous rock; however, at Caraon it is seen as a great intrusive mass over a quarter of a mile in width, bordered on both sides by well-defined schist zones. A very interesting thing about this intrusive mass is its various phases. I have traced this dike across the country for a mile or so and have seen it grade from a quartz-feldspar-muscovite rock into one of quartz and muscovite, quartz and feldspar with no mica, and finally into a phase of pure quartz. The rock is quite white, slightly greenish in the weathered portions, fairly coarse grained and it possesses an uneven fracture. It consists of quartz, feldspar (plagioclase) and muscovite mica, although sometimes the micas when decomposed give the appearance of being biotite. There are also phases which have a very granular appearance.

Microscopic.—The rock is seen very largely to consist of quartz in both large and minute irregular grains. Some feldspar, usually dirty and cloudy, occurs, apparently plagioclose, as all that I made out to be feldspar at all showed twinning of the albite order. I was able to find symmetrical extinction in only one specimen and in this the angle found was 10° to 12°, which would identify the mineral as an oligoclase. Pericline combined with the albite twinning also occurs.

No trace of micas remains in the slides which were examined, but dirty-greenish aggregates of decomposition products only could be observed; under high power these were seen to be very minute, low, doubly-refracting bodies, which may be zoisites and chlorites. I should judge from the appearance of the slides that there had been a considerable occurrence of deformative stresses throughout the entire mass from which these samples came, as minute granulation is quite marked throughout the slide. This deformation probably dates back to the time of the intrusion of the mass.

Analysis.[4]

	Per cent.
SiO_2	72.56
Al_2O_3	15.13
Fe_2O_3	2.54
MgO	.95
CaO	2.01
Na_2O	5.06
K_2O	.56
H_2O+110°	.03+100
H_2O-110°	.93+110
TiO_2	Trace.
P_2O_5	None.
MnO	.46

[4] Analysis by Mr. L. A. Salinger, Chemical Division, Bureau of Science.

THE BOJEADOR ANDESITE.

The main road from Pasuquin to Nagpartian follows the coast and just a little past Bojeador light-house it cuts through a spur of the same hill on which the light-house stands. At this cutting the rock which is exposed is a light-colored andesite, very like some phases occurring at Mariveles. This flow seems to constitute the main part of the rock mass of Cape Bojeador. I regret that time was not available for a close study of the field relations of this flow; it doubtless has some very close connection in point of time with the "eruptive conglomerate." Many of the bowlders and fragments in the latter mass are petrographically quite similar to this flow. I found no other signs of this andesite flow anywhere else in the district. This flow, in all probability, is to be correlated with the great andesite sheet of Benguet, described by Mr. A. J. Eveland,[5] formerly geologist of this Bureau, with a similar flow in Marinduque, and with that of Cebu.[6] In the latter island it is found unconformably above the upturned and truncated coal measures and below the orbitoidal limestone capping. I shall not here enter into a detailed description, as farther below I describe sections of practically identical rocks from the "eruptive conglomerate."

"ERUPTIVE CONGLOMERATE."

A long, narrow, black and exceedingly forbidding ridge begins near Cape Bojeador and extends due east therefrom for several miles at an elevation of 1,500 feet; it is composed of masses of lava bowlders, some rounded, more of them angular and fragmentary, all in a very mixed condition and in a matrix which is also of volcanic origin. For purposes of convenience, and from its analogy to a similar formation in Borneo described by Verbeek,[7] I have called this an *eruptive conglomerate;* it is, more strictly speaking, an agglomerate.

A line of much lower hills also exists, extending eastward between the main road and the coast as far as Baruyen River; these hills are of the same material. The manganese oxide which will be discussed in subsequent pages occurs in the minute veins between the harder fragments in the decomposed matrix.

Plate V, fig. 5, is a view taken from one portion of this ridge, looking down on the low country near the coast. Some trails in the uncut jungle are more difficult, but apart from these, this one across this ridge is the roughest one which it has been my lot to travel in the Philippines. I looked in vain for some sign of an old vent, some extinct crater, which would throw light on the point of origin of this formation. A close examination of the ridge itself showed some crater-like depressions, always incomplete, but I finally decided that all of these forms could be produced in the ordinary processes of erosion.

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[5] Eveland, A. J.: Geology and geography of the Baguio Mineral District, to be published in the next number of *this Journal.*

[6] Smith, W. D.: Physiography of Cebu Island, *this Journal* (1906), 1, 1044.

[7] Verbeek, R. D. M.: Die Eocänformation von Borneo und ihre Versteinerungen, Cassel (1875), 7.

Next, I turned to the coast. Here I found ash beds, sedimentaries and lava flows, but no sign of an extinct crater. After the study of this portion of the country, the Babuyanes Islands and their circular arrangement, highly suggestive of a drowned crater, occurred to me. The distance, and the fact that elevation and not subsidence has been the rule in this region, precluded my making use of their existence to explain the mystery. Later I examined the roughly circular, flat-bottomed valley in which Nagpartian lies. It is not at all improbable that this valley, now filled with sediment, may at one time have been the vent, or it may have contained one or more vents from which all this eruptive material issued. Several different colors and textures of rock were found among the bowlders, but they are all petrographically essentially the same.

In the hand specimen, the rock is grayish to reddish, hard, somewhat vesicular, fine grained, with an aphanitic groundmass containing feldspar phenocrysts of 1 to 2 millimeters in length.

Microscopic.—The slide contains plagioclose feldspar and augite in a fine, andesitic groundmass; that is, a mass consisting of minute, lath-shaped feldspar crystals, so arranged as in places to show a distinct flow structure. The angles of the feldspar phenocrysts were found to vary from 26° to 31°, and, as these were symmetrical angles measured on the albite twinning, they indicate that labradorite is probably the particular one of the series constituting this rock. Occasional Carlsbad, Baveno and Pericline twins were noted; zonal growth is quite common. (Pl. VI, fig. 6.) The other phenocrystic constituent of the slide is augite, often exhibiting good basal sections with prismatic twinning. In prismatic sections extinction angles no higher than 40° were noted. Magnetite accompanied by hematite stains occurred almost entirely in some slides ingrown with the feldspars, in others it was confined to the groundmass. The writer has examined almost identical rocks from Baguio, Benguet Province. The similarity to the recent volcanics of western America, Alaska and Japan and in fact of many parts of the Philippine Archipelago is very noteworthy, making it appear to be quite evident than the great Pacific Arc, or at least the northern part of it, is one petrographic province as indeed Mr. Becker [8] has already suggested.

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[8] Becker, G. F.: Geology of the Philippine Islands, *U. S. G. S. 21st An. Rep.* (1900), 518.

METAMORPHISM.

The evidence is plentiful of there having been considerable dynamic metamorphism in former times in this region. It is not local, but regional, for there are very few parts of the Archipelago which do not exhibit it. In the Ilocos country the metamorphism can be considered under two heads, as follows:

Serpentinization—dominated by chemical alteration.

Formation of schists—dominated by physical re-formation.

I have not yet seen any evidence of there being contact metamorphism, although I expect it to be discovered after further search, and then somewhere along the border of the granite (f. n.).

Serpentinization is by far the most important from an economic standpoint, and therefore it will first be considered. Nearly every hand specimen of the basal rock in the district shows some alteration, and this alteration is usually to serpentine. The asbestos deposits occur in veins and pockets in the fractured serpentine masses. This serpentinization is quite common in Philippine basic rocks; I have seen it on Batan Island, and along portions of the Zambales coast. Mr. Becker also cites several other localities. In Ilocos Norte it is more pronounced on the Dungn-Dungon estate on the Baruyen River. At Dalumat, near Pasuquin and in fact wherever the pyroxenite mass in exposed, some degree of serpentinization will be seen. In all the slides so far examined from this region the alteration has been from rhombic pyroxenes. (See Pl. VII, fig. 7.) I have noted the alteration from olivine in other parts of the Islands but not here.

The pseudo-conglomerate in the serpentine.—Very characteristic features of the serpentine formation are in the brecciation and the conglomeratic appearance in many localities. I have called this type of rock a pseudo-conglomerate. This broken and bowldery condition is quite marked and is confined largely to the borders of the mass, along or near the schist zone. Some of the fragments are small, angular blocks; others, immense rounded bowlders. "Slickensides" is a very characteristic feature in this part of the formation, and the brecciation in this and the jasper formation afford ample proof of the tremendous dynamic movements in this region. That these dynamic forces are still at work is quite probable, as Luzon is subject to frequent earthquakes, although it is true that this part of the island is less liable to have them occur than the regions farther south. The photograph (Pl. V, fig. 8) is of this pseudo-conglomerate near the Baruyen River at Baruyen Hill.

The schists.—Schistose rocks are apparently scattered quite generally throughout the length of Luzon, as well as in the other islands of the group; naturally, they are confined to the mountainous portions where there has been a considerable amount of dynamic movement. In Ilocos

Norte we find them in a narrow, irregular belt bordering the granite (f. n.) dike which runs roughly north and south across the country.

At Dalumat I found magnetite, talc, mica (several species), actinolite and chlorite schists, all in a very much disturbed and mixed condition, but in this region the mica and talc schists prevail; farther to the north near Dungn-Dungon, magnetite schists are better developed, and there is also a very feeble development of eclogite. I found, from my study of schists and eclogites from the Coast Ranges of California, that the metamorphism of sedimentary rocks usually produced gneisses and schists, whereas the eclogites could in some cases at least be traced back to an igneous antecedent. However, in the Ilocos Norte region I have not in mind a single instance where I could actually trace these transformations in the field. This much, and only this, we can be sure of at the present time; that is, that the mica and talc schists are found between the granite (f. n.) intrusive mass and the later sediments; the magnetite schists and eclogites are more intimately associated in the field with the basal igneous mass, usually near its edges.

MINERALS OF THE SCHISTS.

Actinolite schists.—These are to be found in patches everywhere bordering the serpentine area. Some of the rocks are entirely made up of long actinolite crystals, while in others actinolite is only one of the several constituents. Slides from two different rocks from near Pine View Point were examined. The first one consists largely of a mass of actinolite fragments with interstitial, more or less rounded feldspar grains, rarely showing polysynthetic twinning, the whole complex with every appearance of having been derived from a sediment; extreme granulation is a feature of this rock. The second one is made up almost entirely of actinolite with probably some interstitial chlorite. In parallel, polarized light the actinolite shows marked dichroism. $\mathfrak{a}$ = colorless. $\mathfrak{c}$ = olive green. The actinolite does not occur in whole, unbroken crystal sections, but is in a very much frayed state, in fibers which are the result of breaking along the cleavage lines parallel to $\acute{c}$.

Mica and micaceous schists.—Nearly every species of mica known to mineralogy can be found, it seems, in the schistose areas near Pasuquin. These minerals all occur in small pieces, seldom as complete crystals, they occur very irregularly along shearing planes. The lighter micas such as muscovite, paragonite, etc., and micaceous talc seem to predominate.

In the cut which Mr. Burdette has put into the side of the hill at Dalumat, I saw pockets of nearly all species of mica, but always in a more or less comminuted condition. These micas could very possibly be manufactured into lubricants and paints. One green, chlorite variety should find some use as a paint in these Islands, particulary in decorating the frames of the numerous cheap pictures of saints, etc., which the Chinese sell to the natives. According to "Mineral Industry" for 1905, scrap mica finds commercial use for boiler and pipe lagging, for roofing and fireproofing materials, as a lubricant and for decorative work, wall papers and paints. If any small sheets should be found they could be worked up into "micanite," now extensively employed in insulating certain parts of dynamos.

Extensive development of mica schists occur in this region, paragonite and margarite being the predominant micas.

Scales of this white mica, when viewed in a petrographic microscope, show a fine interference figure with an axial angle of 37°. A qualitative analysis demonstrates the presence of sodium and calcium, so that we probably have both paragonite, the sodium variety, and margarite, the calcium mica.

Magnetite schist.—Many outcrops of schists occur in the vicinity of the Baruyen River and magnetite schist, in which the magnetite cubes and octahedra attain a diameter of 10 millimeters or more, is found among these.

Epidote-magnetite schist.—This rock, in thin section, consists largely of a felty mass of actinolite and chlorite with phenocrysts of magnetite and epidote. The magnetite occurs in diamond and octagonal sections, also is rounded and irregular grains; the epidote, in idiomorphic crystal sections is on the average 0.67 by 0.08 millimeter. These epidotes are distinguished by high relief, parallel extinction and the characteristic, irregular fracture. The difference in absorpton along the a and b axes is as follows: a=colorless, b=straw yellow.

Conclusions in regard to the schists.—It is quite possible that some of these schists may be metamorphosed ancient sediments, although this is not very probable. The presumption is that they are of very recent origin. We doubtless have as much reason for placing them in the Archean as have some writers in the case of the crystalline schists of Formosa, but there is absolutely no paleontologic evidence in either case.[9]

THE SEDIMENTARY FORMATIONS.

The following sedimentary formations are found in this region, flanking the basal core of the rocks and in some places as residual patches, in tiers, resting upon the older formations:

The order is from above downward, and only tentative, as contacts or sections including more than one formation are very infrequent.

Raised coral reefs.
Marl beds.
Orbitoidal limestone.
Ash beds with sandy shales alternating.
Calcareous sandstone.
Coarse grained sandstone and shale beds alternating.
Ferruginous cherts and slates, jasper.

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[9] Outlines of the Geology of Japan, Tokyo (1902), **26**, 33.

In discussing these formations it will be best to begin with the one which is stratigraphically the lowest.

The Jasper Formation (*Dungn-Dungan*).—This formation was first discovered on the Dungn-Dungan estate, and it has derived its name therefrom. It is perhaps the most interesting of any with which this paper deals. It is exceedingly limited in its outcroppings and quite variable in its phases, never being encountered as a continuous formation, but only as isolated outcrops, which reveal little or nothing as to its position.

On the left bank of the Baruyen River, about 200 feet up the slope, seemingly projecting out of the talus of a hill which I know to have a serpentine core, is an outcropping of this formation; here it appears to possess more the character of a slate, the fissile slabs varying in thickness from 5 millimeters to several centimeters. It is of a dirty red color, fine grained and compact. The slabs are exceedingly hard, but easily break off with a ringing sound. In the Caraon River this formation is very much brecciated (Pl. VII, fig. 9), but the angular fragments have been firmly recemented. Float bowlders were seen in this same stream; they are wholly without structure and in color are a brilliant red, resembling very much the jasper associated with the hematite deposits in Michigan and Minnesota in the United States. The resemblance of some phases of this formation to the radiolarian chert of the San Francisco peninsula which I have seen, also led me to make some sections, with the following results:

DESCRIPTION OF THE SECTIONS.

In thin section this rock is seen to consist of a fine-grained, amorphous groundmass of chalcedonic silica, copiusly stained with oxide of iron, with almost innumerable round and oval areas which are more or less clear. (Pl. IX, fig. 10.) In ordinary light the whole section resembles sections of some of the radiolarian cherts of the San Francisco peninsula,[10] to judge from my memory of them and from descriptions.

Between crossed nicols these areas are seen to be filled with a doubly refracting material which often exhibits undulating extinction, and which is in a more or less granulated condition; by using a higher power (number 4 objective, 3 ocular), it is clearly evident that this granulated material, with every optical character of chalcedonic silica, constitutes both the groundmass and the clear areas. (Pl. VIII, fig. 11.)

I quote somewhat at length from Mr. Lawson's paper [11] because of the similarity existing between the phenomena presented here and those observed in the San Francisco rocks, and also because of the excellence of his petrographic descriptions:

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[10] Lawson, A. C.: Geology of the San Francisco Peninsula, *15 Ann. Rept. U. S. G. S.*, 420–426.

[11] *Loc. cit.*

> "When a suitable series of these cherts is viewed in thin section under the microscope a gradation may be observed from those which are composed almost wholly of amorphous or isotropic silica to those which are holocrystalline aggregates of quartz granules. In the most isotropic sections there are, however, numerous minute scattered points in the field, which polarize light. These can not be separated in any sharp way by the highest powers from the isotropic base. They are not inclusions, but centers of incipient crystallization in the amorphous rock. They correspond to the products of devitrification in glass. In other slides these centers of crystallization are much more thickly crowded, and definite areas composed of interlocking granules of quartz appear, interlocking, also, with the isotropic base. The actual boundaries of these areas can be made out only with difficulty and uncertainty, owing to the fact that the quartz granules are characterized by a molecular tension, which results in an undulatory extinction as the stage is resolved between crossed nicols. In still other slides these areas coalesce and the proportion of amorphous base to the whole rock becomes very small * * *.
>
> "Scattered through the slides of these cherts, whether they be amorphous, semicrystalline, or holocrystalline, there may usually be observed, in ordinary light, circular or oval clear spaces or clear rings free from pigment. Between crossed nicols these clear spaces are seen to be occupied by chalcedony. They are the casts of *Radiolaria,* and occasionally remnants of the spines and latticework may be detected. These areas and rings are usually more sharply defined in the amorphous cherts, and are somewhat indefinite in outline, yet distinct as areas, in the holocrystalline varieties. In thin section they are most readily observed in the red cherts, by reason of the contrast which they make with the pigmented matrix.
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> * * * * * * *
>
> "It thus seems to the writer that the bulk of the silica can not be proved to be the extremely altered débris of *Radiolaria.* The direct petrographical suggestion is that they are chemical precipitates. If now we accept this hypothesis, it becomes apparent that there are three possible sources for the silica so precipitated, viz: (1) Siliceous springs in the bottom of the ocean, similar to those well known in volcanic regions; (2) radiolarian and other siliceous remains, which may have become entirely dissolved in sea water; and (3) volcanic ejectamenta, which may have become similarly dissolved."

I believe that these clear spaces in the Ilocos Norte slides do not represent individual casts, for I find no trace of "latticework" and but little to compare with the spines found in the California cherts; in fact, I think these clear, circular and oval areas represent pores in the tests of such Nasselarians as *Podocrytis, Bothryocampe,* etc.; as yet I have been unable to make any specific determinations from these slides.

The Bangui Sandstone.—On the slopes of Monte Inmenso I found a very coarse-grained, friable sandstone the beds of which on the average measure 2 feet in thickness, dipping at rather high angles, from 45°

to 65°. These sandstone beds alternate with thin seams of shale, of from 2 to 6 inches in thickness. The sandstone is of a dirty-brown color, while the shale is more of a buff; both the sandstone and the shale appear to be unfossiliferous, as a diligent search for fossils was unrewarded even by the poorest cast or fragment of a shell, or of vegetable matter. There also appeared to be no conglomerate between the sandstone and the underlying serpentine, nor was any indication of contact metamorphism visible.

The resemblance between this sandstone and some phases of the San Francisco formation in the Coast Range near San Francisco at once impressed me; however, from this we need not argue any close connection, save that the sediments originated from the degradation of similar rocks.

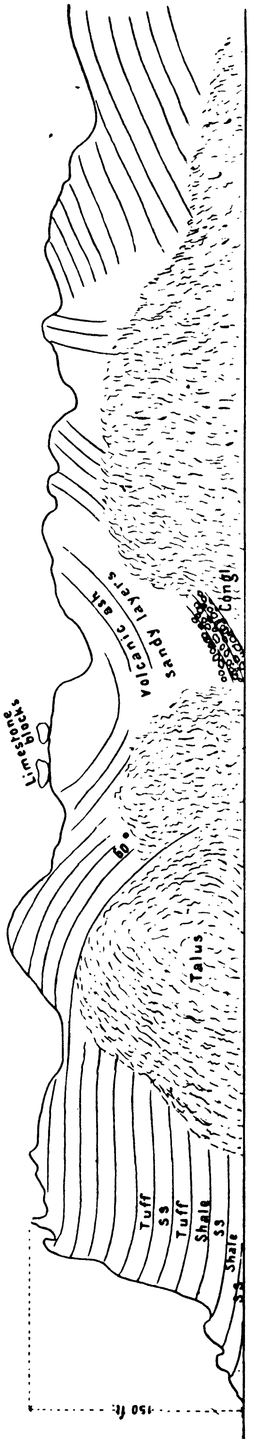
I have called this formation Bangui Sandstone because of its typical occurrence near that pueblo, where however, it is exposed in a more horizontal position, in a great cliff of 50 feet or more.

Pasuquin arenaceous Limestone Formation.—An arenaceous limestone, dipping on the average of 25° to the east and southeast is encountered in going across the river at Pasuquin in a northeasterly direction; the trail up the hill approximately crosses the strike of the beds the outcrops of which form a succession of small terraces or steps.

The only indications of fossils which I encountered were a series of snake-like markings which strongly resemble similar impressions in the Cambrian sandstone. However, some of these in the Pasuquin formation are larger than any the writer has yet seen, in some instances they are nearly 2 inches in diameter and several feet in length. Several small casts of what I believe to be Pteropoda were found; in fact one of these is unmistakably a species of *Cleodora.*

I am told by Mr. Burdette, who knows this country perhaps better than anyone else, that this formation can be followed in a semicircular course all the way to Bangui, with the igneous mass to the left and the sedimentaries to the right.

The Negra Tuff and Ash beds.—Two of the most conspicuous points scenically as well as geologically along the entire north coast of Ilocos Norte are Punta Negra, and Punta Blanca which is very close to the former. Exposure of beds of tuff, sandstone and shale alternating occur at these two points. I estimated the cliff of Punta Blanca to be 150 feet high, a sheer wall, the beds being approximately horizontal. A short distance to the east, opposite the place where the manganese is being opened up, these same beds are tilted at a high angle. (Pl. X, fig. 12.) Below is a sketch of the exposure along this part of the coast:



[Horizontal distance, one-half mile approximately.]

FIG. 13.—SKETCH OF STRATA ON NORTH SHORE AT PUNTAS NEGRA AND BLANCA.

To judge from the sequence of sediments, there were evidently periods of normal erosion, alternating with times of volcanic activity, which resulted in a shower of pumice and lapilli coming from some unknown source; in any event there must be some close connection between the origin of the "eruptive conglomerate" and the tuff beds.

This north stretch of the coast is exceedingly rugged and wild, having been likened by a Scotchman residing in Nagpartian to the scenery along his own coast of Scotland. If at times some of the little coves do not harbor a smuggler or two it is the fault of the smuggler for not taking advantage of exceptional opportunities. With the exception of a boat of the *Compañía General de Tabacos de Filipinas* once a week, only small native *virays* are seen in these lonely waters.

Punta Negra and Punta Blanca Orbitoidal Limestone.—Overlying and unconformable to both the ash beds and the manganiferous eruptive material on the coast between Puntas Negra and Blanca there is a limestone capping to the hills, the remnant of what was at one time a more extensive formation. This limestone is very coarse grained, vesicular and is largely made up of triturated, hard parts of various shell-bearing invertebrates. Among the numerous foraminiferal tests to be seen in the slides from this rock, those of *Orbitoides* belonging to the *Lepidocycline* group are seen, these are of the same species as the ones from many other parts of the Islands, and they agree very closely with *L. insulae-natalis* Chapman and Jones, from the reef limestones of New Hebrides[12] and Christmas Islands.[13] This limestone is Miocene and it is equivalent to the upper limestone of Cebu, of Mindanao and central and southern Luzon. Although I have not been able to follow these formations very continuously in the field, I place this limestone as being younger than the ash beds of Punta Negra, and older than the marl beds of Bacarra and Laoag. There is some very interesting stratigraphy to be worked out at this place in the future.

Laoag Marl Beds.—Some low, rounded hills, hardly larger than good sized dunes, but which are remnants of a higher land are encountered on the highway between the towns of Laoag and Bacarra. A road cut through one of these in one case gives a section of about 40 feet, showing a cream-colored to brownish, sandy marl which contains some remarkably preserved and fresh looking fossil shells. These belong to the following genera:

Pisania.
Triton.
Ricinula.
Pleurotoma.
Turbo.
Dentalium.
Oliva.
Crystallaria.

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[12] Chapman, Fred: Notes on the Older Tertiary Foraminiferal Rocks on the West Coast of Santo, New Herbrides, *Proc. Linn. Soc.* N. S. Wales (1905), **2**, 271.

[13] Mon. of Christmas Island, *Brit. Mus. Nat. Hist.* (1900), 242.

As nearly as I could ascertain, these beds are horizontal. I should say, to judge from the included forms, that the deposit is of shallow water origin, but not very close to the littoral. Despite their low topographic position, I consider these beds stratigraphically to be above both the Pasuquin and the Bangui formations, and from the very recent appearance of all the fossils and their close relationship to forms now living in the Philippine seas with which I have compared most of them, I shall provisionally refer them to the *Pleistocene*.

Raised Coral Reefs (*Currimao*).—Only bare mention will be made of these, as I could only note them in passing; suffice it to say that coral reefs elevated to the extent of 10 to 12 feet above high tide exist close to the water's edge, and behind these the topography by its terraced appearance indicates the existence of one or more raised shelves at about 100 feet elevation, and possibly a still higher one.

I have not made a quantitative study of the species in the raised and living reefs, but even a cursory study shows them to be quite similar. Much light is thrown on the formation of our great limestone beds in the Philippines by a close examination of these raised reefs. In the limestone in many cases a great branching coral head may be seen standing upright and in the same position in which it grew, surrounded by a hardened matrix of limestone which consists of hardened coral sand and which contains fragments of corals and shells. Spines of *Echinodermata* are always plentiful in this matrix.

These raised reefs have a very even upper surface, due to the manner of growth of corals. Doubtless, they have not been long in their elevated position for it is well known that these reefs rapidly harden and become strong after being exposed to the air. Mr. Becker[14] has already particularly referred to this phenomenon.

SUMMARY OF THE GENERAL GEOLOGY.

From the foregoing it is evident that here we have a region of greatly varied geology, probably exhibiting more diverse features than most parts of the Archipelago; it is primarily a district of metamorphism and this metamorphism is regional rather than local.

Upon a batholith of diorite there were laid down certain sediments which by great dynamic forces have became altered into entirely new rocks in which practically every mineral has been formed anew out of older and entirely different minerals. Granulite dikes have enhanced this general metamorphism. Still later over all these basement rocks and crystalline schists, there have been deposited sediments which, though often found tilted at high angles, show little subsequent change in their mineral composition. Among these sediments we find limestones, sandstones, shales, marls, ash and tuff beds. Serpentinized pyroxenite occurs in this region, but it is difficult always to make out its exact relation to the other formations, it is doubtedless of a laccolithic nature, subsequently exposed by erosion. On Plate XI, I have attempted to draw an ideal section across the country. It must be considered to be merely tentative.

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[14] G. F. Becker: Geology of the Philippines, *21st An. Rept. U. S. Geol. Sur.* (1902) 561.

The existence of marl beds with very recent fossils, some of which still retain a trace of their original coloring, and extensive, raised coral reefs containing corals in no wise different from those growing in the adjacent water, indicate that in this part of the world at least the main feature of the Pleistocene was not glaciation, but normal marine deposition; there was also undoubtedly at the same time much subaërial erosion and deposition.

In this connection I wish to offer the suggestion that the entirely unusual emphasis generally given to glacial deposits as the chief characteristic of the Pleistocene is quite unwarranted. In many parts of the world at least, glacial deposits appear quite insignificant to those who live along the sea border.

In conclusion I shall again draw attention to the remarkable similarity between the geology of the eastern and western portions of the great Pacific arc. Below I have drawn up a comparative table which is, however, not meant to be more than suggestive. The right-hand column is taken from Professor Lawson's paper, cited above.

Table of comparative stratigraphy.

Ilocos Norte.	San Francisco (Cal.) peninsula.
Raised coral reefs. Marl beds with recent shells.	The terrace formations Pleistocene and later.
Shales and tuff beds alternating, andesite flows.	Merced series (Pliocene). Thick volume of sendiments with one stratum of volcanic ash.
Orbitoidal limestone.	Montery series (Miocene) white siliceous shale.
Pasuquin calcareous sandstone.	Light colored cavernous sandstone—Tejon (?) Age.
Baruyen series (shales, sandstone and jasper). Serpentinized pyroxenite.	Franciscan series associated with peridotite serpentines. Laccolithic conglomerate, San Francisco sandstone foraminiferal, radiolarian cherts.
Granulite—Dike.	Montara granite.
Crystalline schists.	Crystalline limestone, age unknown.

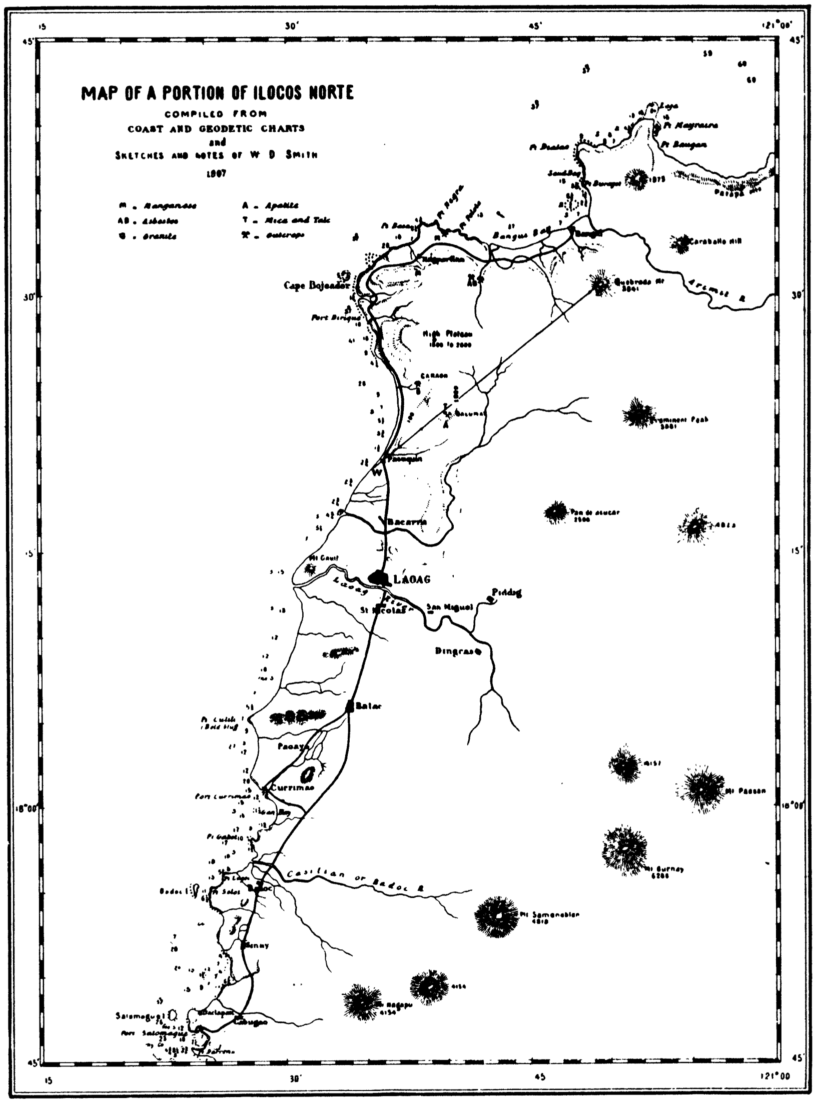
MAP OF A PORTION OF ILOCOS NORTE
COMPILED FROM
COAST AND GEODETIC CHARTS
and
SKETCHES AND NOTES OF W D SMITH
1907
M . Manganese
AB . Asbestos
G . Granite
A . Apatite
T . Mica and Talc
X . Outcrops
Cape Bojeador
Port Dirique
High Plateau
Bangui Bay
Bangui
Pt Dialao
Pt Magnaura
Caraballo Hill
Quebrada Mt
Pagudpud
Pasuquin
Bacarra
LAOAG
San Nicolas
San Miguel
Piddig
Dingras
Batac
Paoay
Currimao
Port Currimao
Pt Culili
Casilian or Badoc R
Badoc
Mt Samanablan
Mt Burnay
Mt Paoson
Banna
Salomague
Port Salomague
Cabugao
15
30'
45'
121° 00'
18° 00'

PLATE II.

GEOLOGY—ECONOMIC.

INTRODUCTION.

The northern part of this province, although not yet a mineral producing district, bids fair to yield some rich returns, first of all from its non-metallic minerals, and possibly later from the metalliferous deposits which in all likelihood are also to be found.

Dynamic metamorphism which has prevailed throughout most of the region is directly responsible for the formation of many minerals, both of economic value and otherwise, which are not to be found in many other parts of the Islands. The most important of the economic deposits is asbestos, a collective name for more than one mineral, and actinolite, a calcium hornblende predominating in the schists.

The following is a list of the minerals and rocks which will probably prove to be of greater or less value: *Asbestos, manganese oxide, apatite, mica* and *talc, ocher, quartz, feldspar* and *building stone.*

Asbestos is found as a *"stockwerk"* or ramifying vein deposit in the serpentine formation of the district; the manganese, in the form of an oxide, is a sedimentary deposit, concentrates from veinlets ramifying the eruptive conglomerate mass; the mica and talc are entirely secondary formations in the schist zone; ocher occurs as a concentrate from the weathered igneous mass; the quartz and feldspar form a part of the granulite mass; apatite was encountered near the granulite dike, its exact relations being unknown. Building stone encountered here, both the granulite and the Pasuquin calcareous sandstone, is suitable for certain grades of construction.

Of course we must continually bear in mind that the value of each and every one of these products depends upon the market, after the available quantity is assured. There seems to be no reasonable doubt but that all the asbestos which can be mined can be used both in the Philippines and elsewhere, as the production of this mineral is not at present sufficiently great to interfere with the disposal of the Philippine product at good figures. If any considerable quantity of first grade fiber is opened up, handsome returns should be realized. The best Canadan fiber from the Thetford mines brings $80 (United States currency) per ton and the second grade from $13 to $50 [15] (New York prices).

It would be premature to say much about the market for manganese oxide but we are reasonably certain of one thing, there is no local demand for it and whether it could compete in the outside market is not at all certain; furthermore, there is at least one other locality in the Islands which will be a competitor, as reports by various engineers and prospectors assert that there is a considerable deposit of good manganese ore in the

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[15] *U. S. G. S.* Press Bulletin, Monday a. m., July 9 (1906).

Island of Masbate and a deposit, concerning the extent or grade of which I have as yet received no reports, has been cut through along the new road from Capas to Iba in Luzon.

There can be no question about the sale of apatite, the phosphate, for it is always valuable as a fertilizer. This mineral and the organic phosphate deposit, guano, are sure to find a market, if not at present in the Philippines where the soil has never yet been deeply disturbed for agricultural uses, certainly among the Japanese firms, who should take considerable quantities.

Mica and talc, as they are encountered in these deposits, can only be utilized in minor ways, such as for insulating parts of electrical apparatus, for lubricants, "frosting" for Christmas effects, etc., and it is doubtful if there is as yet any local demand and also it is improbable that there would be any great call from the outside.

There should be a good, steady, local market for the ocher for, if I am correctly informed, the Manila Chinamen handle greater or less quantities of the red and yellow mineral paints. If the day of huge red barns and granaries is ever inaugurated in these Islands, then there should be a considerable use for pigment of this class.

The granulated quartz and feldspar might be made use of in the manufacture of glass, which is just being begun in Manila, and in the ceramics which are already being manufactured. Although a pure quartz sand, such as one would get from crushed quartzite, would be better, doubtless a good grade of silica could be obtained by separating the quartz from the feldspar in this deposit and using it in glass manufacture, whereas the feldspar could be employed in the making of pottery.

The building stone would undoubtedly have to depend on an extremely local demand. The Hongkong granite, a decidedly better and prettier stone, can very probably be imported to Manila at a figure which would be the same or less than that for which the Ilocos Norte granulite could be placed on the market.

Asbestos.—The asbestos of Ilocos Norte is of two varieties, the "parallel" and the "cross fiber," with the former species predominating.

The "cross fiber" variety, true chrysotile, has up to the present scarcely made its appearance. This, it is hardly necessary to state, is the kind most eagerly sought. The "parallel fiber" asbestos is a variety of mineral distinct from that of the "cross fiber" and consists largely of the minerals anthophyllite and tremolite, both amphiboles; the latter being the mineral chrysotile, having its origin in serpentine. The anthophyllite does not necessarily have any connection with serpentine.

In order to bring the differences clearly before the reader, some of whom may not be mineralogists, I have culled data of a mineralogical nature regarding these and other varieties of asbestos from the best sources at hand.

According to Merrill,[16] there are four varieties of mineral substances coming under the general term of "asbestos." There are:

1. True asbestos.
2. Anthophyllite.
3. Chrysotile (fibrous serpentine).
4. Crocidolite.

Physical characteristics.—From Merrill's Non-Metallic Minerals.

Asbestos.—The true asbestos is of a white or gray color, sometimes greenish or stained yellowish by iron oxide. Its fibrous structure is, however, its most marked characteristic, the entire mass of material as taken from the parent rock being susceptible of being shredded up into fine fibers sometimes several feet in length. In the better varieties the fibers are sufficiently elastic to permit of their being woven into cloth. Often, however, through the effect of weathering or other agencies, the fibers are brittle and suitable only for felts and other non-conducting materials. The shape of an asbestos fiber is, as a rule, polygonal in outline and of quite uniform diameter; often, however, the fibers are splinter-like, running into fine needle-like points at the extremity. The diameters of these fibers are quite variable, and, indeed, in many instances there seems no practical limit to the shredding. Down to a diameter of 0.002 millimeter and sometimes to even 0.001 millimeter the fibers retain their uniform diameter and polygonal outlines. Beyond this, however, they become splinter-like and irregular as above noted.

The mineral anthophyllite, like amphibole, occurs in both massive, platy, and fibrous forms, the fibrous form being to the unaided eye indistinguishable from the true asbestos.

Chemically this is a normal metasilicate of magnesia of the formula $(Mg, Fe)SiO_3$, differing, it will be observed, from asbestos proper in containing no appreciable amount of lime. It further differs in crystallization in the orthorhombic rather than monoclinic system, a feature which is determinable only with the aid of a microscope. The shape and size of the fibers are essentially the same as true asbestos. The fibrous variety of serpentine to which the name asbestos is commercially given is a hydrated metasilicate of magnesia of the formula $H_4Mg_3Si_2O_9$ with usually a part of the magnesia replaced by ferrous iron. It differs, it will be observed, from asbestos and anthophyllite in carrying nearly 14 per cent of combined water and from the first named in containing no lime. This mineral is in most cases readily distinguished from either of the others by its soft, silk-like fibers and further by the fact that it is more or less decomposed by acids. As found in nature the material is of lively oil-yellow or greenish color, compact and quite hard, but may be readily reduced to the white, fluffy, fibrous state by beating, hand-picking, or running between rollers. The length of the fiber is quite variable, rarely exceeding 6 inches, but of very smooth, uniform diameter and great flexibility.

The mineral crocidolite, although somewhat resembling fibrous serpentine, belongs properly to the amphibole group. Chemically it is anhydrous silicate of iron and soda, the iron existing in both the sesquioxide and protoxide states. More or less lime and magnesia may be present as combined impurities. The color varies from lavender-blue to greenish, the fibers being silky-like serpentine, but with a slightly harsh feeling.

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[16] Merrill, G. P.: The Non-Metallic Minerals (1904), 181.

Another fibrous mineral which is common in the Ilocos Norte region is an asbestiform *actinolite*. The analysis shows a considerable percentage of lime. The cleavage across the long axis of the fiber would certainly militate against it in spinning.

Analysis of asbestiform actinolite[17] (*Ilocos Norte*).

	Per cent.
SiO_2	57.50
Al_2O_3	.87
Fe_2O_3	.33
FeO	1.50
MgO	23.80
CaO	11.42
Na_2O	.75
K_2O	.06
H_2O	.20
Lose on ignition	2.98
	99.41

Plate XI, fig. 14, is a photograph of a specimen of Ilocos Norte chrysotile.

Field relations.—In the field there are two noteworthy forms of occurrence. One is the formation of parallel fiber in the Dalumat and Baruyen schist areas, and the other is the "pocket" formation on the Dungn-Dungan estate; that on the Tug-a-tug promises to be very much the same as that of the Dungn-Dungan. The Dalumat and Baruyen asbestos is confined almost entirely to shear zones, and hence is of local and limited occurrence.

A rather large pocket of inferior asbestos consisting largely of tremolite and talc was struck in the shaft in the *estero,* tributary to the Baruyen, but there are also several small veins of "cross fiber" material of good appearance which makes it more than likely that if this locality were diligently worked, some good results would be obtained. Below is a cut showing the appearance of the workings at this place. (Pl. IX, fig. 15.)

Chrysotile or fibrous serpentine is the principal product of the Canadian mines and its characteristic occurrence in that region is as a fine fiber, usually not over 1 centimeter in length, running crosswise from wall to wall of the vein. The serpentine in the Canadian mines is penetrated in every direction by innumerable, narrow veins filled with this fibrous serpentine. Occasionally, this fiber attains a length of 17 centimeters.

It is my opinion that the mining and dressing operations will be much the same in the Ilocos region as in Quebec; that is, the whole containing rock will be mined, crushed in rotary crushers, run through a "cyclone blower," and dried in rotary kilns.

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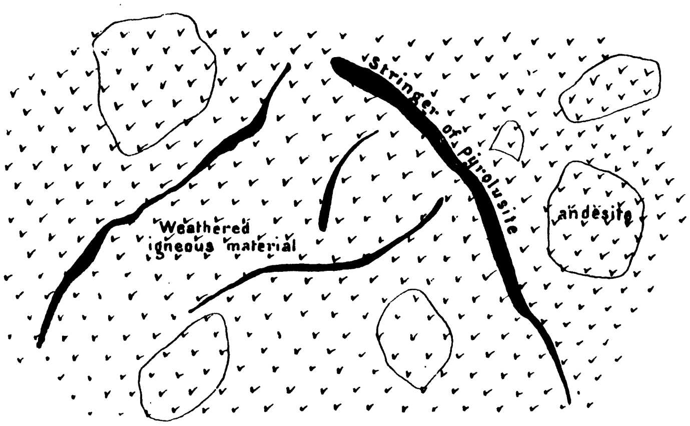
[17] Analysis by L. A. Salinger, Chemical Division, Bureau of Science.

The modern methods of mining and of treatment of asbestos are described very fully by Cirkel[18] in reports of the Canadian Mines Branch.

Manganese.—Scattered over the surface of the ground of the "eruptive conglomerate" region of Nagpartian, one can see innumerable small nodules of pyrolusite and limonite. For some time I was at considerable loss to know just where these came from, for by digging beneath the surface in certain spots at least, I could not discover any source, in fact these nodules seem to lie only on the surface, some in stream beds, but others also on the hilltops. A later examination of the sides of the Nagpartian road where a great washout had taken pace, revealed many very small veinlets of manganese oxide between the bowlders of eruptive material. The matrix appeared to be a sort of tuff, quite soft and yielding. The veinlets are approximately of a width corresponding to the thickness of the surface nodules, all of which are more or less flat and longer than they are wide. This surface material therefore simply represents the concentrates found as the material below has weathered and as the manganese veins became freed from the matrix. A sketch of the actual ocurrence will best present these relations (fig. 16).



[Width of veinlets 5 mm. to 50 mm.]

FIG. 16.

There seems to be even a greater concentration of the manganese and limonite in the Nagpartian hills, but the nature of the country and the difficulties attending transportation preclude any probability of development in that locality.

Between Punta Negra and Punta Blanca perhaps the best prospect for the mining of this ore is seen. It is at this pont, within a very few minutes walk of the sea, that Mr. F. D. Burdette has been at work with a large force of native laborers. The geological relations obtaining here are shown in the diagram below (fig. 17):

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[18] Cirkel, Fritz: Asbestos—Mines Branch, Dept. Int., Ottawa, Canada (1905).

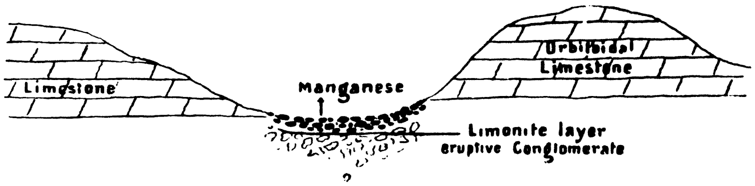

FIG. 17.

Not over 2 feet of concentrates were exposed at the time of the writer's visit to this place; only after further work will it be ascertained whether there is more than one bed of concentrates. If sufficient quantity of this ore could be found it would be best to "riddle" it, afterward sack it and transport it by means of cargadores or a cableway down to a storehouse on the beach and from there it can be shipped during the southwest monsoon. The lateral distribution seems to be sufficiently extensive but at the time of my inspection I had some fear as to the vertical extent of the deposits. Recent development work has in some measure shown this to be well grounded.

Analysis of the manganese ore.[19]

	Per cent.
SiO_2	1.10
Fe_2O_3	4.04
H_2O—110°	10.58
H_2O+110°	
P_2O_5	.02
MnO_2	77.51
	93.25
Metallic Mn	48.93

Apatite.[20]—Nothing very definite can be said about the occurrence of this mineral at the present writing. Some fairly good crystals, sufficient for making some important crystallographic measurements, were sent in to us by Mr. Burdette over a year ago. These, in color and superficially in crystal form, so closely resemble the mineral olivine that they were at the time classed as such. Later it was found that they belonged to

[19] Analysis by Mr. L. A. Salinger, Chemical Division, Bureau of Science.

[20] This mineral was found near the trail to the "Thetford" workings at Dalumat, but at the time I was there a landslide had concealed all traces of it. This is the only place where Mr. Burdette has found it.

the hexagonal system and blowpipe tests gave a reaction for phosphorus and no silica. The complete analysis is as follows:

Analysis of the apatite.

	Per cent.
Fe_2O_3	.36
Al_2O_3	
MgO	.71
CaO	54.62
H_2O at 110°	.02
P_2O_5	40.95
F (undetermined)	3.14
Cl	Trace.
Loss on ignition	0.20
	100.00

By using the contact goniometer the angle between the faces (0001) and $(10\bar{1}1)$ was found to be a trifle less than 40°. After making the necessary calculations, I found this would give the figures 0.7266 for $\dot{c}$, which is a little low, 0.7346 being the usual figures, though there is some fluctuation.

Such crystallographic data as I could work out on the imperfect material in our possession are given below.

Color, lemon yellow on fresh fracture; luster, resinous; fracture, irregular; hardness, 5 to 6; specific gravity, 3.10; system of crystallization, hexagonal.

Forms.	Angles.
$c=(0001)$	$cx=42°$
$m=(10\bar{1}0)$	
$x=(10\bar{1}1)$	$as=43°$
$a=(11\bar{2}0)$	
$s=(11\bar{2}1)$	$am=60°$
	$\dot{c}=.7266$

The finding of apatite in this region associated with the rock pyroxenite is interesting and may lead to highly valuable results when it is recalled that this is the same association obtaining in the apatite deposits of Canada.

Mica and talc.—In the "Thetford" workings (Ilocos Norte) the most abundant minerals are the micas and the micaceous chlorites and talc. Muscovite, biotite, margarite, phlogopite, pennine and talc were noted, all very mixed in pockets and along shearing planes; much actinolite also accompanied these minerals. No large sheets of mica were seen, in fact all these micas occur in rather a triturated condition, so that as I have mentioned above, they could find use only in the industries which employ ground material. It is quite possible, although somewhat improbable, that good sheet mica may be discovered in this region.

Agalite, or fibrous talc as it is commercially known, is extensively used in the manufacture of paper. Like asbestos, it has a distinct fibrous structure which causes it to blend well with the vegetable fibers of paper pulp and admits of its retention in paper without the great loss which accompanies the use of sulphate of lime, china clay, and other mineral loading materials.

According to the statistics of the New York Geological Survey for 1905, there were produced 67,000 short tons of fibrous talc, valued at $469,000 which gives an average of $7 per ton. Practically the entire output of this material finds its way to the paper mills. Mr. Richmond, chief of the Division of Chemistry of this Bureau, has with this use in mind examined a specimen of tremolite altered on the exterior to talc. He reports as follows: "Judged by the physical properties of the substance examined, it would be considered of very good quality for the above named purpose. It grinds well, is of a good color, and is especially free from grit."

The analyses[21] of the Ilocos tremolite and talc, and a standard agalite for comparison, are as follows:

Constituents.	Ilocos mineral. Per cent.	Agalite. Per cent.
SiO_2	57.62	61.82
Al_2O_3	1.36	1.59
Fe_2O_3	1.66	
MgO	24.18	29.98
CaO	13.38	3.65
H_2O	2.33	2.6–2.8
	100.53	99.64
Specific gravity	2.84	2.67

Doubtless only the portion of this deposit represented by talc would be valuable as a filler in paper pulp, but the tremolite is sufficiently high in magnesium to make it of use for pipe lagging, etc.

Mineral paint.—Not much can be said concerning the mineral paint, red and yellow ocher, save that it occurs in considerable quantity at Dalumat, bordering the igneous mass of the plateau known locally as Babuy Flats. This ocher has resulted from the decay of the igneous rock which is rich in iron. There is a vast quantity of it available, and with cheap labor, as women and children could be used to clean and sack it, and by employing native *cargadores* there should be a fair profit in it. This ocher is nothing more or less than iron oxide in various stages of hydration, and by burning, the hydration could be regulated so as to secure several different colors. The yellow is limonite, the red, hematite. A determination of silica and iron by Mr. Salinger gave 23.5 per cent for the silica and 9.8 per cent ferric oxide.

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[21] Analyses by Mr. L. A. Salinger, Chemical Division, Bureau of Science.

Feldspar—Quartz and building stone.—These have all been sufficiently commented upon in previous pages so that repetition is not necessary. However, one thing should be mentioned, namely that analysis shows the feldspar to be albite, the soda plagioclose. A physical examination of the quartz grains proves this material to be suitable for glass manufacture, etc.

Analysis of the granulite.

Constituents.	"Silica." Per cent.	"Granulite." Per cent.
SiO_2	65.86	72.56
Al_2O_3	19.97	15.13
Fe_2O_3	.47	2.54
MgO	1.24	.95
CaO	.08	2.01
Na_2O	1.78	5.06
K_2O	.20	.56
H_2O-110°	.00	.03
H_2O+110°	.75	.93
Ti_2O	.03	Trace.
P_2O_5	None.	None.
MnO	.35	.46
	90.73	100.43

Prospecting and development work.—There are several prospectors in this field, but only one organized company was doing any systematic development work at the time of my visit. This is known as the "Ilocos Mining Company," whose representative in the field is Mr. F. D. Burdette, a man of considerable familiarity with Oriental mining operations, geology and labor. Mr. Burdette's efforts are now being concentrated on the asbestos of the Dungn-Dungan estate, and the manganese of Punta Negra. The Punta Negra property is known as the "Cecile group."

It is my opinion that tin might be discovered in this region, and it might be recommended that efforts be concentrated on the streams heading near or in the granulite dike which runs northeast from Dalumat.

TRANSPORTATION.

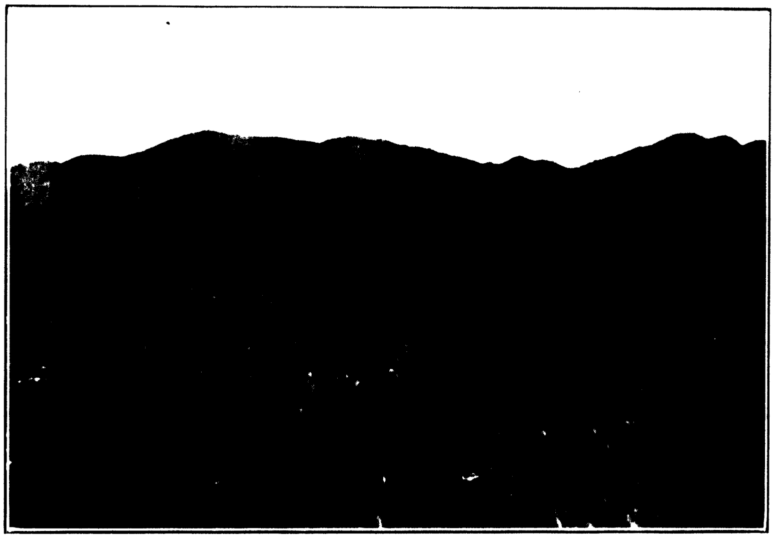
This is one of the worst features connected with mining operations in this region. The roads which exist are in wretched condition; in the Nagpartian district there is only one, which closely follows the coast. To my knowledge there is not a single steel or stone bridge in the province, and many of the wooden ones are in a deplorable state of preservation. There are no bridges over the Laoag, the Bacarra, the Baruyen, and Bamban Rivers, only bamboo rafts are available, and at certain seasons of the year these can not be used. The transportation of supplies is entirely dependent upon bull-carts and *cargadores.* The distance from Pasuquin to Nagpartian is only about one-fifth that from Pasuquin to Vigan, but the time consumed in making the trip with bull-carts is about the same. Traveling with a bull-cart is slow and somewhat difficult, but the rate of pay is not high, it being usually about 25 centavos per mile, although sometimes this depends upon whether you are going to or from Laoag. *Cargadores* can easily be procured if it does not happen to be the rice harvesting season when they are wanted, their cost being about 35 centavos per man per day and subsistence. Rice or ground corn is sufficient for them. The conditions affecting transportation on the water have been given elsewhere.

LABOR.

The Ilocanos make very good laborers and are always willing to work, although they are remarkably untutored in the kind of labor required in mining. One great difficulty comes in the harvesting season; for then they are very reluctant to leave the rice fields. Thirty-five centavos a day and subsistence is the usual rate at present. The general labor conditions here are the same as in other parts of the Islands and of the Orient. When the native and his dialect are better understood it becomes evident that he is a much better workman than some would have us believe. Brutality on the part of the foremen, even apart from the underlying moral objections, will not for a moment accomplish anything in the handling of these peoples.

ILLUSTRATIONS.

PLATE I. Outline map of portion of Luzon showing location of Ilocos Norte.
II. Map of portion of Ilocos Norte showing location of mineral districts.
III. Fig. 1. View of plain and mountains in the background.
Fig. 2. View of upland country between Pasuquin and Bangui.
IV. Fig. 3. Another view of upland country between Pasuquin and Bangui.
Fig. 4. Looking across the upland country toward the Cordillera, Caraballo del Norte.
V. Fig. 5. View from Nagpartian Ridge toward the coast.
Fig. 8. The pseudo-congomerate in the serpentine.
VI. Fig. 6. Feldspar phenocryst in andesite, showing twinning and zonal growth. Magnified about 14 times.
Fig. 7. Thin section of peroxenite. 14 times.
VII. Fig. 9. Brecciated jasper.
VIII. Fig. 10. Section of radiolarian (?) chert. Magnified 120 times.
Fig. 11. Same magnified 350 times.
IX. Fig. 12. Tilted ash, tuff and sand beds on Punta Negra.
Fig. 15. Open cut in serpentine and "asbestos," Dungn-Dungan.
X. Fig. 14. Crysotile from Dungn-Dungan, Ilocos Norte.
XI. Ideal section from Pasuquin northeast to Cordillera along line west to east (Plate II).
Figs. 13, 16, and 17, woodcuts, explained in the text.



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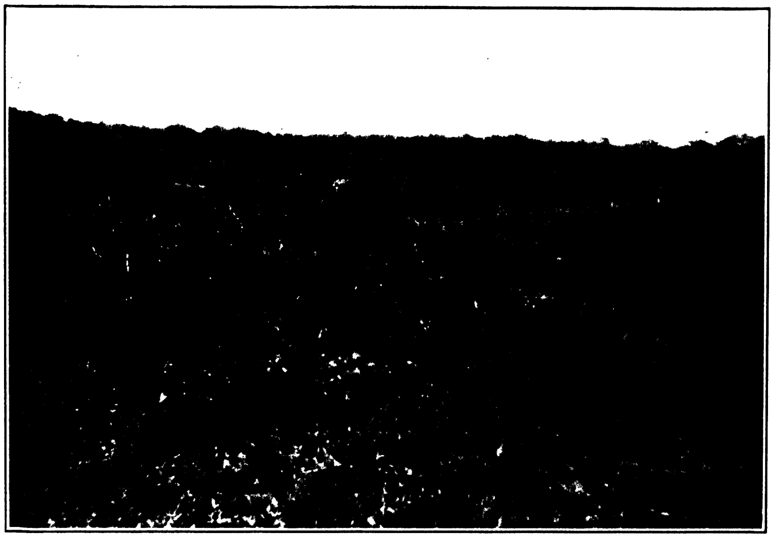
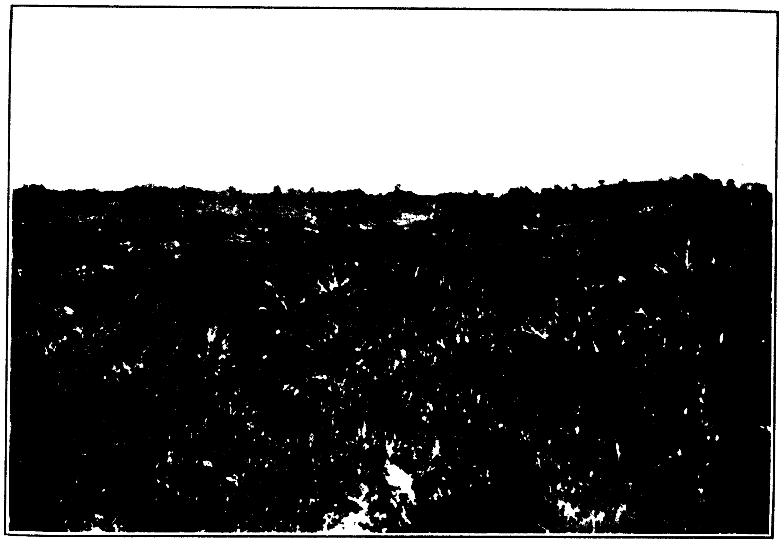


FIG. 2.

PLATE III.



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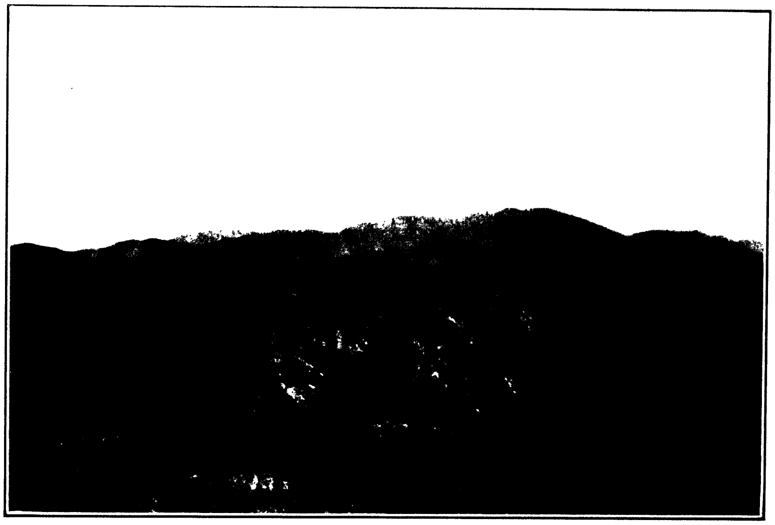


FIG. 4.

PLATE IV.

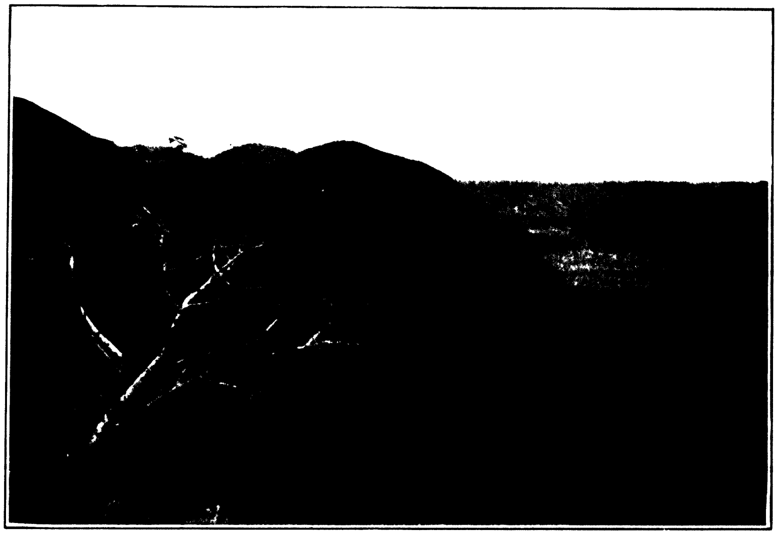


FIG. 5.

FIG. 8.

PLATE V.

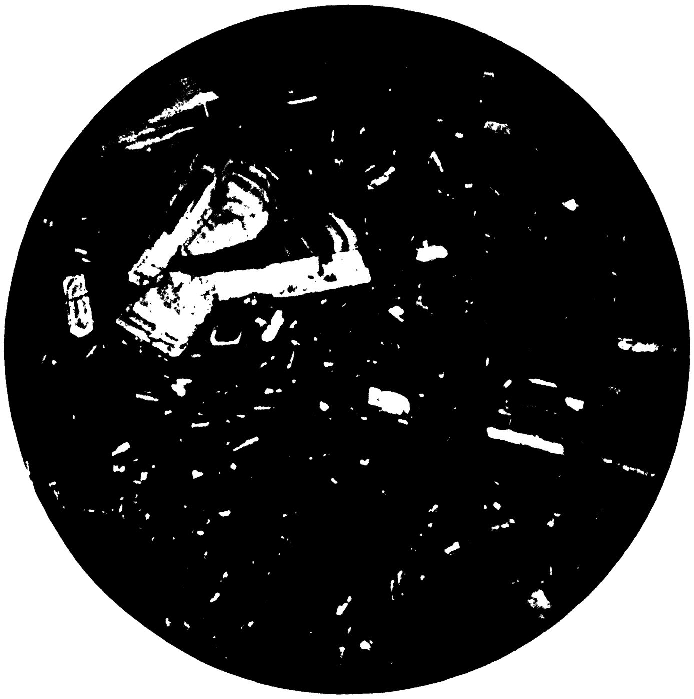


FIG. 6.

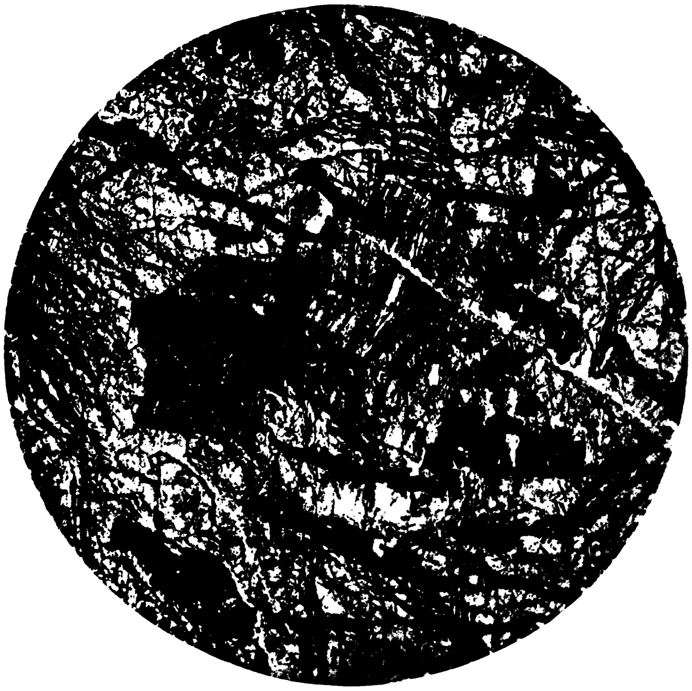


FIG. 7.

PLATE VI.

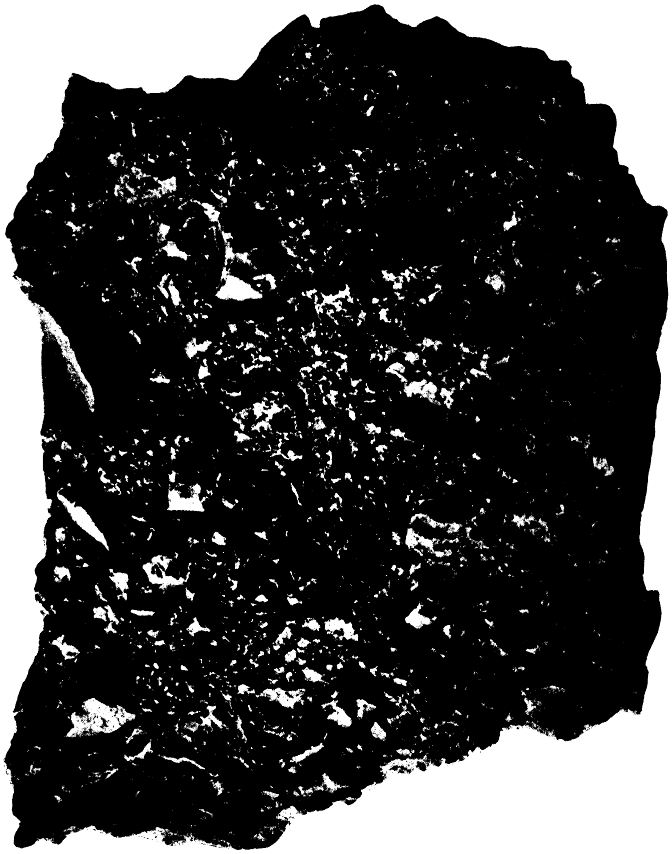


FIG. 9.

PLATE VII.

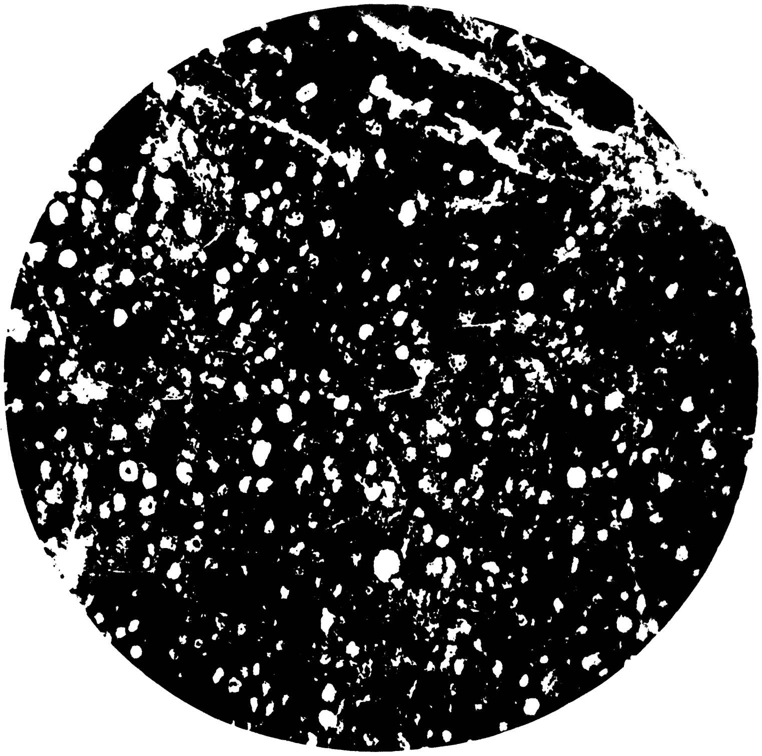


FIG. 10.

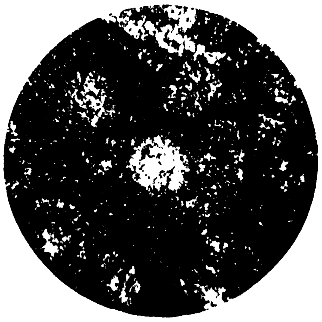


FIG. 11.

PLATE VIII.

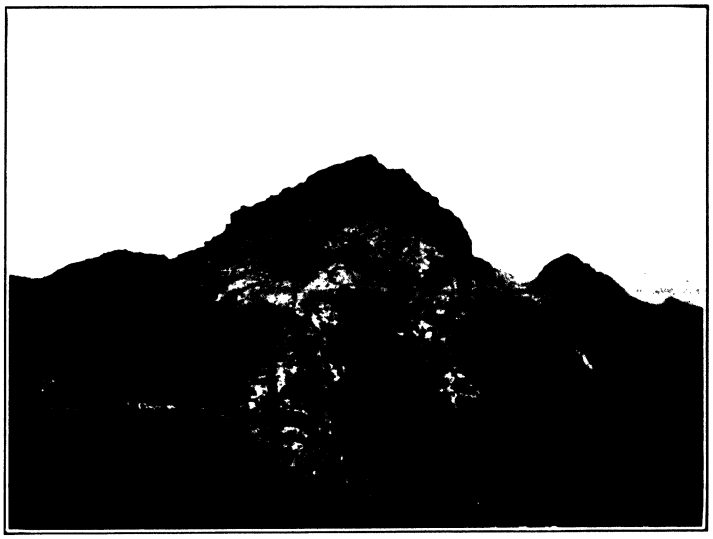


FIG. 12.

FIG. 15.

PLATE IX.

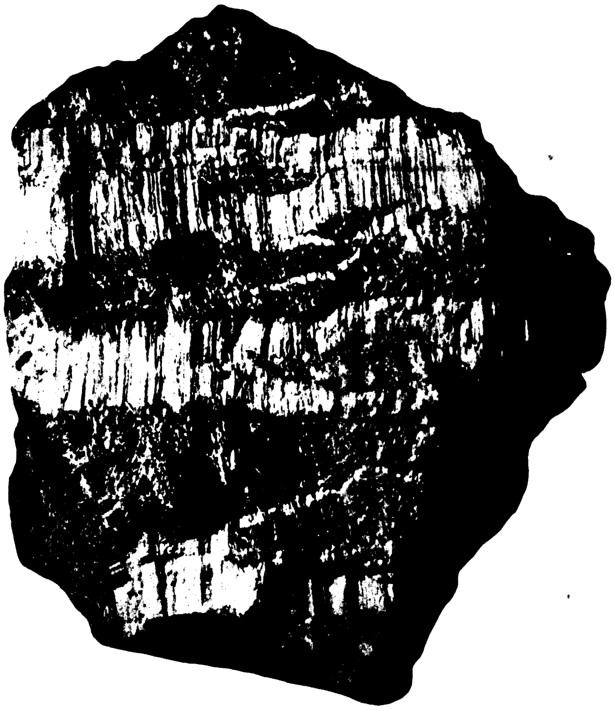
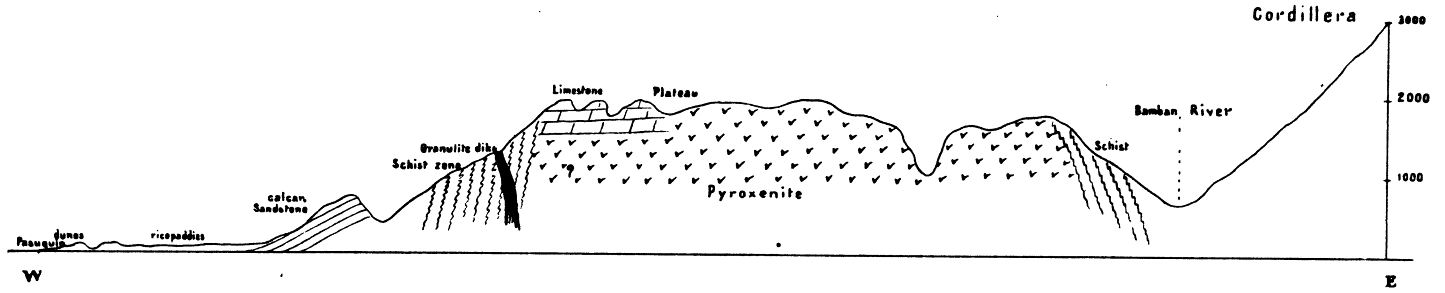


FIG. 14.

PLATE X.



IDEAL SECTION FROM PASUQUIN NORTHEAST TO CORDILLERA ALONG LINE WEST TO EAST (PL. II).

PLATE XI.

THE ASCENT OF MOUNT HALCON, MINDORO.[1]

By Elmer D. Merrill.

(*From the botanical section of the Biological Laboratory, Bureau of Science.*)

The Philippine Archipelago is essentially mountainous. Many of the high peaks have been ascended by white men, although accurate accounts as to when, by whom and under what circumstances the explorations were made are to be found in but few instances. On making local inquiries in regard to the ascent of mountains one usually hears vague rumors of previous attempts to climb them, entailing great difficulties, privations and not infrequently loss of life. Usually, however, it is quite impossible to verify many of these rumors for, as a rule, natives living in the vicinity of the mountains have very little information regarding them, and because of prevailing superstitions it frequently is difficult to induce them to accompany a party when the known object of the expedition is to ascend a high mountain.

Mountain climbing in the Tropics, especially in such tropical countries as the Philippines, can scarcely be classed as a sport, and here as in other parts of Malaya, the higher mountains have usually not been ascended by persons for the pure love of mountain climbing, but by those who have had some special object in view, such as the study of the fauna, flora or geology of the region. In other words, the high peaks of the Philippines, as in the Malayan region generally, have been ascended mostly for what was to be secured on them.

Mount Apo in southeastern Mindanao is the highest in the Philippines, yet the first recorded ascent which I have been able to find is that of *J. Montano,* a Frenchman, who reached the summit in October, 1880.[2] Montano, however, states that an attempt was made by the Spaniards in 1852 under the direction of *Oyanguren,* which failed after the loss of twenty men, and that in 1870, *Real,* then the governor of Davao, made another, but unsuccessful endeavor, to reach the summit. Dr. *A. Schadenberg* ascended Apo in February, 1882, and *Otto Koch* must have made the ascent at about the same time for Vidal[3] figures some species of plants from the summit of Apo which were collected by the latter. Since 1880 Mount Apo has been climbed many times by various persons, to my knowledge by at least ten Americans within the past five years, and I am informed by those who have made the ascent that there are comparatively few difficulties to be encountered, either in the approach to the mountain or in its ascent. Nevertheless, as late as 1905 I have seen accounts in Manila newspapers "of the first ascent of Mount Apo."

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[1] This is the first of a series of articles on geographical subjects which it is proposed to publish.—P. C. F.

[2] Voyage aux Philippines et en Malasie (1886), 245–264.

[3] Sinopsis, Atlas (1883).

We have no records that Mount Malindang, the second highest mountain in the Philippines, had been ascended previous to 1906, when in May of that year Maj. *E. A. Mearns* and *W. I. Hutchinson* and their party reached the summit. Mounts Banajao, Pinatubo, Tonglon, Datá, Solis, and Mayón, all in Luzon, Canlaon in Negros, Madiaas in Panay, all 7,000 feet in altitude or higher, have been ascended one or many times each, by various persons, and secondary mountains such as Mariveles, Arayat, Maquiling, Isarog and Iriga in Luzon, Silay in Negros, Pulgar and Victoria in Palawan, and many others, are more or less known.

Halcon the third highest peak in the Philippines, is situated in the north-central part of Mindoro. With no known trails leading to it, surrounded by dense forests, cut off from the coast by difficult ridges and large rivers subject to enormous and appalling floods, it stood seemingly inaccessible. Its location is perhaps in the most humid part of the Philippines, where the rains continue for nine months in the year, in a region geographically quite unknown and inhabited by a sparse population of entirely wild and very timid people, and on an island regarding which there is a widespread and generally accepted belief as to its unhealthfulness. Although within 100 miles of Manila and not more than 15 from Calapan, the capital of Mindoro, so far as I have been able to determine it remained unconquered up to the year 1906.

MINDORO.

Mindoro ranks as seventh in size among the islands of the Philippine Archipelago, being located a little north of the center of the entire group and having an area of approximately 3,851 square miles. In general outline it is roughly triangular, its greatest length being from northwest to southeast, 110 miles, its greatest breadth from northeast to southwest, 56 miles. Geographically, it is in closer proximity to Luzon than to any other large island of the group.

Verde Island passage, separating Mindoro from the south coast of Batangas Province, Luzon, is but 7½ miles in width in its narrowest part between Escarceo Point, Mindoro, and Malocot Point, Luzon. The small island of Lubang lies 15 miles north of the northwest point, while the larger island of Marinduque is 23 miles east of the central part of Mindoro. Tablas is situated 31 miles east of southern Mindoro, and Panay 36½ miles east of south. Busuanga, the beginning of the Palawan chain, is 33 miles southwest.

The name Mindoro is of Spanish origin, taken from *Mina de oro*, meaning mine of gold, applied by the earlier Spanish explorers. It came no doubt from tales imparted to them by the natives of the fabulous mineral wealth of the island, yet for over three and three-quarters centuries this reputed golden treasure has remained undiscovered. The ancient native name of the island was Mait.

Topographically, Mindoro is exceedingly rough and the interior is very imperfectly understood; it is known locally as "the Africa of the Philippines." The mountains in the north culminate in the Halcon Range, the highest peak being exceeded among Philippine mountains only by Apo and Malindang, both in Mindanao.

The census of the Philippine Islands taken in 1903 gives the total population of Mindoro as 28,361, of which 21,097 are classified as civilized and 7,264 as wild. As comparatively little is known regarding the Mangyans, the aborigines inhabiting the interior, the latter figure must be considered as approximate rather than exact. The civilized inhabitants are confined entirely to the coast region, the Tagalogs predominating in the north, the Visayans in the south.

Undoubtedly the Negritos are the aboriginal inhabitants of the island and the Mangyans are the descendents of Negrito and Malayan stock. They are confined entirely to the interior of Mindoro, except in the southern part, where one or two towns of semicivilized Mangyans are located on the coast. Capt. R. G. Offley,[4] United States Army, Governor of Mindoro, states that they are non-Christian but not savages by nature or habit, that they will run at sight of a stranger if his coming and intentions have not previously been announced. They are divided into several groups, the chief among which are the Buquit, Bañgon and Batanganes; these roam in bunches or by families, the oldest acting as chief; they are willing workers, but they have no knowledge whatever of agriculture, and the Christian Filipino avails himself of the fact that they do not know the value of money by giving a handful of salt for a banca, while the price of a small working bolo to a Mangyan has been known to be ten years of servitude. The best description of these people which I have seen is that given by Dean C. Worcester,[5] to whose book the reader is referred. In regard to the Mangyans as a whole, Captain Offley's statement is inaccurate in some respects, for the ones we encountered on the north slopes of Halcon have fairly permanent habitations and also possess a decided knowledge of agriculture, although it is of a very primitive kind. We saw but three representatives of these people on the entire trip, an old man, a boy and a girl, but we passed through numerous clearings, some of them several hundreds of acres in extent where there were houses; however, the inhabitants fled at our approach. In one clearing, at an altitude of about 3,000 feet, we found in cultivation: rice, corn, sugar-cane, bananas, yams, sweet potatoes, tomatoes, beans, squashes and taro, while domestic pigs and chickens were in evidence. Most of the dwellings were very small and primitive, consisting of a platform raised two or three feet above the ground, with a thin palm-leaf roof and usually without walls, but in the clearing mentioned above we found an unusually large and well-constructed house about 20 feet long, 15 feet wide and 12 feet from the floor to the apex of the roof. It was firmly constructed, elevated on posts about 6 feet above the ground, with a pole floor and grass-thatched roof and walls and was evidently the abode of a person of prominence in a local tribe. Such a pretentious house certainly is unusual among the Mangyans.

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[4] Census of the Philippine Islands (1903), 2: 547.

[5] The Philippine Islands and their People (1901), 375–377; 406–418.

Mindoro has attained and still retains a widespread but apparently not entirely deserved reputation for unhealthfulness, frequently being spoken of as "the white man's grave." In spite of adverse reports as to the unwholesomeness of Mindoro and the prevalence of fevers and various tropical diseases in the island, on our trip, which extended over forty days in the height of the rainy season when on nearly every day all members of the party were wet at least once and sometimes all day and for many days in succession, working our way slowly through drenched forests, fording streams and much of the time on short rations, none of the Americans in the party were sick and among the twenty-five natives employed, only three contracted fever and then in a very mild form. In common with previous explorers in Mindoro, we found the leeches very abundant and exceedingly troublesome at the lower altitudes but we became entirely free of them after reaching the height of about 5,000 feet. Ordinary brown soap was found to be an excellent leech repellant and this was given each day to our native carriers who smeared it on their naked legs. Previous experience had taught us that canvas or leather leggings are entirely unsatisfactory as a protection against leeches, and all the Americans in the party were equipped with woolen "puttees." These proved to be more satisfactory and gave absolute protection against the attacks of leeches. Quinine was issued regularly to all members of the party.

MOUNT HALCON.

The name Halcon is of Spanish origin signifying falcon, but the application of this name to the mountain is not clear. As usual, the native names vary. According to Lieut. Fitzhugh Lee's report of his trip made across Mindoro in 1904, the natives living at the mouth of the Baco River knew it as the Alag Mountain. We found those living at Subaan, only 7 miles from Baco, speaking of it as the Baco.

The altitude of the highest peak is given on Spanish charts as 3,865 meters, while our uncorrected aneroid readings determine an altitude of 9,000 feet, both of these records apparently, being too high. In April, 1906, a triangulation party of the Coast and Geodetic Survey, under the direction of Mr. O. W. Ferguson, estimated the height of the mountain as 8,504 feet, the mean of three determinations from as many different stations. The same party ascertained the geographical coördinates of the highest peak to be latitude N. 13° 15′ 46″, longitude E. 120° 59′ 29″.

Viewed from the coast, Halcon appears to present no particular difficulties so far as the ascent is concerned. It is a long, more or less broken ridge running from east to west, presenting steep slopes, especially on the north, but with three pronounced spurs with more gradual slopes leading from it, one to the east, one to the south and one to the west. The crest line of these spurs present rather gradual slopes, although they are steep in places. Several subsidiary spurs lead off from the main range in various directions, notably to the north. Difficulties encountered in making the ascent of Halcon, as is the case with most Philippine mountains, were found to be not so much in the actual climbing as in the approach to the mountain, the fording of streams, the crossing of ridges, the cutting of trails through the dense vegetation and in the transportation of necessary supplies and equipment.

The highest peak of Halcon shows no signs whatever of ever having been visited by human beings, and as it would be a physical impossibility for any person to reach the summit without extensive trail cutting, it seems evident that in recent years at least, it has never been visited by man. Several attempts to reach the top of the mountain have been made and in the past three centuries it is possible, but not probable, that some of the early Spanish explorers in their search for the fabulous mineral wealth of Mindoro, might have made the ascent. I have been able to find no account whatever of attempts made by the Spaniards, and the utter inaccuracy of Spanish maps as to the location of Halcon Peak and the course of the Alag and Baco rivers would indicate that they had no positive knowledge whatever of this part of Mindoro. In fact, on many maps such a large river as the Alag is not indicated at all, although it joins the Baco at tide water and at less than 3 miles from the coast.

PREVIOUS ASCENTS OF THE MOUNTAIN.

In April, 1891, *Dean C. Worcester* visited some Mangyan clearings on the slopes of Mount Halcon, probably ascending to about 2,500 or 3,000 feet. However, so far as I can learn he made no attempt to reach the summit, but his trip in this vicinity is the first one of which I have any knowledge. The reader is referred to his own account of his Mindoro experiences.[6]

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[6] *Loc. cit.*

In October, 1895, *John Whitehead,* an English naturalist tried to reach the summit, but although he did not succeed in attaining the highest peak he was undoubtedly the first person to reach an altitude of 6,000 feet. As Whitehead's primary object was to collect objects of natural history and especially birds, he apparently made no serious attempt to reach the highest point on the mountain. I can do no better here than to quote from W. R. Ogilvie-Grant's[7] account of Whitehead's experience on Mount Halcon.

> On the 19th of Octber, 1895, he (Whitehead) left Manila with a staff of seven collectors for the Island of Mindoro, with the object of exploring the well-wooded highlands of this comparatively little known island, and returned to Manila on the 16th of February, 1896, after four months' absence. The results of this expedition are, Mr. Whitehead considers, by no means satisfactory, for at the time of his visit the wet season was at its height and, owing to the almost continuous rains, collecting could be carried on only under the greatest difficulties. He tells us that during his stay on Mindoro seventy days out of a hundred were very wet, twenty dull and drizzling, while but ten were comparatively bright and fine; so it can be understood easily that he was unable to do as much as he had hoped.
>
> Unfortunately, he experienced great trouble with his collectors, all of whom suffered at one time or another from fever, and took every opportunity of misbehaving. One man robbed him of his money, while others, left at the foot of the mountain to make a lowland collection, did practically nothing during many weeks, and sold both gun-caps and powder to the natives. He characterizes his Mindoro collection as representing "four months' very hard work and slow starvation"
>
> On landing in Mindoro a guide was engaged as pilot to the high ground, but this worthy led the expedition by a wrong path, and after a long day's march in the usual deluge of rain, Mr. Whitehead found himself on the bank of a fine river surrounded by the most dense and magnificent forest, where he was forced to remain for ten days waiting for porters. It was here that the expedition was nearly wrecked, the river coming down in a tremendous flood with very little warning. The camp had been pitched about 20 feet above the river, which at this part was about 200 yards wide, but in less than twelve hours, fortunately in daylight, the water was running from 2 to 3 feet deep like a mill race through Mr. Whitehead's tent, while his men had to escape in canoes from another house lower down the river, where most of the less portable boxes had been left.
>
> By great exertions all the baggage was saved. "I have," writes Mr. Whitehead, "seen a good deal of Tropics, but I never encountered such deluges, such incessant rains, or such thousands of leeches. The leeches quite crippled two of my men, and one of the two caught 'beriberi' so I sent him back to Manila. All the others had fever, but I got off with two mild attacks of dysentery. I was so reduced, from having nothing to eat but tinned foods and rice, that I became quite weak, losing most of my energy at times. In four months I had eaten only five pigeons, two parrots, and some few thrushes, and, with the exception of eggs, there was no other fresh food to be had." Such is life in the highlands of the Philippines.
>
> By making friends with the true aborigines of Mindoro (the Mangyans) the twenty-five porters required to carry the baggage to the mountains were at last

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[7] Grant, W. R. Ogilvie: On the Birds of the Philippine Islands, Part 7. The Highlands of Mindoro. With field notes by John Whitehead. *Ibis:* (1906) VIII, **6**, 457.

obtained, and, after two days' march under continuous heavy rain, Mr. Whitehead and his men camped at an altitude of 4,500 feet on Mount Dulangan, in the main range of Mindoro. This range of mountains is somewhat horseshoe shaped. Mr. Whitehead continuous: "To cut a long story short, it rained all November, all December and all January; one deluge began on the 11th of December, and was perhaps second only to that which floated Noah and his great zoölogical collection, for it continued until the 6th of January, 1896. But for all this I was in good health the climate being cool, seldom over 60° F., and some nights only 52° F.; the mountain of the east side is perhaps over 8,000 feet, but the ranges are mostly from 5,000 to 6,000 feet. I was guided by the natives to a part that attained nearly 6,000 feet, but we could not reach the crest of the mountain from this position. The undergrowth is very dense and, without cutting paths, impossible to get through."

In April, 1904, Lieutenant *Fitzhugh Lee, Jr.*, Twelfth United States Cavalry, accompanied by three other officers, Mr. *H. D. McCaskey*, Chief of the Philippine Mining Bureau, ten Americans soldiers and thirty native carriers, left Camp McGrath, Batangas, Luzon, with the object of crossing northern Mindoro and if possible, of making the ascent of Halcon. They landed at the mouth of the Baco River and on April 3 proceeded up that river to the junction of the Alag, following that stream in boats to the head of navigation, an estimated distance of 5½ miles. The Alag was chosen as the most feasible route because its direction is more westerly and because the natives insisted that its source was somewhere in the vicinity of Alag, the local name of Mount Halcon. On April 4 the boats were abandoned, the river having become very shallow and swift. The expedition then followed a narrow trail along the bank, the carriers being assigned about 80 pounds each. The stream was very tortuous, averaging from 50 to 60 yards in width and the party was compelled to ford five or six times during the morning's march. On April 5 the advance was continued up the bed of the river but the loads for the carriers had to be reduced in weight, progress being exceedingly slow and hard, as the rocks in the river bed bruised the carriers' feet. On this day the distance covered was but 3 miles and on the day following but 3½ miles. On the 7th of April progress was reported to be very difficult and dangerous because of the large bowlders in the stream bed, the swift current and the steep cliffs on both sides, and on this day they went but 2½ miles. Lieutenant Lee continues:

> "It seems to be more difficult than we had anticipated to locate Mount Halcon. Our field of vision is very limited, confined as we are in the bottom of a deep cañon with lofty perpendicular walls and a wilderness of vegetation growing out from either side overhead. Just at this time we are particularly anxious to get a bearing on the mountain that we may locate the easiest course for an ascent."

On this days' march several of the party came in contact with some poisonous plant, spoken of a species of "poison ivy,"[8] which on the following days caused them much suffering and inconvenience, eruptions breaking out all over their bodies, and the faces of some individuals swelling so that they could see only with difficulty. On April 8 they succeeded only in covering 2½ miles but they were fortunate in securing the services of a Mangyan as a guide. On the following day, finding further progress up the Alag impossible, they retraced their steps a short distance, leaving the cañon of the Alag and following the bed of a small river flowing from the west,[9] making camp in the bed of this stream at an altitude of 1,500 feet. It rained at intervals during the day and all the night and the party gave up hope of ascending Halcon. On April 10 and 11 they crossed the divide at an altitude of 3,230 feet, striking the headwaters of the Bagbaujan River flowing westward, in these two days suffering much from the attacks of leeches and from the constant rain. On the night of April 12 a camp was made in the narrow cañon of the Bagbaujan but, at 8 p. m., because of the heavy rain and the sudden rise in the river, the water coming up about 5 feet in one-half hour, the party were obliged to desert their tents in the darkness and take shelter on a ledge above. The rain continued until 10 p. m. when the river subsided as fast as it had risen. On the following day they went down the river for a distance of 1¾ miles, being obliged to make use of ropes for scaling the cliffs. This method of procedure continued on the morning of the 14th, but later in the day they came out into a more open country and left the river bed. As much of their food had become wet owing to the prolonged rains, the question of rations became a very serious one and caused the members of the party considerable anxiety. However, after the 14th, no grave difficulties were encountered, the party continued on down the Bagbaujan and reached the mouth of the river on April 19, having been seventeen days in crossing Mindoro.

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[8] Probably *Semecarpus perrottetii* March (*Anacardiaceae*).—E. D. M.

In June, 1906, Lieut. *T. H. Jennings,* Seventh United States Cavalry, accompanied by Mr. *M. L. Merritt* of the Philippine Forestry Bureau, made an attempt to ascend Halcon, but little information regarding their trip and experiences is available other than Mr. Merritt's report, who being ordered to reach Manila on the last of June was obliged to return to Calapan before the highest part of the mountain was reached. The party left Calapan on the morning of June 13, going overland by a trail leading inland, reached the Catuyran River, the south fork of the Baco, on the morning of the succeeding day and proceeded up this for some distance, and then followed a stream known as the Dulangan River which flows from the Halcon Range. Here most of their carriers deserted them, and they were delayed in securing more. Continuing up the Dulangan River on the 16th, they left the bed of the stream on the following day and took one of the ridges, which was followed on the 18th and 19th until they arrived at the place where Whitehead had established his camp in 1895. Up to this point the trail was fair. On June

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[9] Apparently the Bolton River. (See map.)

21, believing that they were on a ridge leading directly up the mountain, they continued up to an altitude of 5,250 feet, the side slopes of the ridge which they were on being described as very steep and extending for 2,000 feet below. Continuing along the ridge for the succeeding days, on June 26 they reached a peak having an altitude of 7,250 feet, but, on the following day in going along the ridge towards the main range, they came to an impassable cañon separating the spur on which they were from the main range, and accordingly plans were made to descend into the deep valley to the west and to follow the ridge beyond. However, Mr. Merritt who was obliged to return to the coast, left the party on the 28th of June and returned to Calapan. Regarding Lieutenant Jennings' experiences after this date we have no information except that he reached Calapan on the 7th of July, having attained the main ridge on Halcon but not the highest peak. Mr. Merritt's report shows that from June 14 to June 27, rainy weather prevailed most of the time.

Previously Lieutenant *Jennings* had made a trip into the interior of Mindoro north of Halcon, following Lieutenant Lee's course up the Baco and Alag Rivers for an estimated distance of 10 miles, where he left the Alag and ascended the ridge to the north, reaching the Binabay River. Mounting the ridge to the north of the Binabay, he followed it for three days, mostly in a westerly direction, finally he recrossed the Binabay River and taking the ridge between it and the Alag River, he continued for five days, going west and somewhat north of west, reaching an altitude of 6,000 feet on a ridge some distance north of Mount Halcon. He reported from his experience on this trip that he did not consider the route from the north a feasible one for the ascent of Halcon, recommending that whoever should make the attempt to climb the mountain, should try a route from the vicinity of Lake Naujan or from the west coast of Mindoro.

OUR OWN ASCENT OF HALCON.

A geographical and biological expedition to Mount Halcon was planned in October, 1906, under the direction and with the support of Maj. Gen. Leonard Wood, its object being to determine some feasible route to the mountain, to ascend the highest peak, to secure as much data as possible and to collect objects of natural history. The party was under the immediate direction of Dr. *E. A. Mearns,* major and surgeon, United States Army, accompanied by Mr. *W. I. Hutchinson,* of the Philippine Forestry Bureau, and myself, with one topographer, one hospital corps man, a sergeant and five privates of the Twenty-fifth Company of Philippine Scouts, two natives assistants for Dr. Mearns, and five native carriers from Antipolo, Luzon. Fifteen additional native carriers were secured at Subaan, Mindoro.

We spent the day after our arrival on the morning of October 31 at Calapan, the capital of Mindoro, in repacking the camp outfit, rations and equipment, and in endeavoring to obtain information regarding Mount Halcon. As we expected, but very little which was definite regarding it could be secured in Calapan. Fortunately, we met an American who had a placer claim on the Binabay River and who had been as far inland as the junction of the Binabay with the Alag. He informed as that a good trail existed from Subaan to the Alag River and although he had no information regarding the country beyond the Alag, he was of the opinion that Halcon could be reached and ascended by this route. Topographically, this seemed to us to be the more direct way, although Lieutenant Jennings had reported his belief that a more feasible route could be found from the south, either by way of the Catuyran River, a tributary of the Baco, from Lake Naujan, or from the west coast. We were already acquainted with Mr. Whitehead's experiences on the Dulangan spur of Halcon and also aware of the fact that Lieutenant Jennings had been unable to reach the highest peak of Halcon by following Whitehead's course, and as a selection of any of the routes suggested by Lieutenant Jennings would have necessitated much more overland travel than by way of the trail leading inland from Subaan to the Alag River, the latter was chosen. Accordingly, two large native boats were secured to take the party and equipment up the coast to Subaan, a small village about 10 miles northwest of Calapan; November 1 was entirely occupied in making this trip, and in securing the native carriers for the journey inland. On the morning of November 2 the party left Subaan for the Binabay River, two scouts remaining behind to guard the food supply and equipment which was not immediately taken forward. As rations for forty days had been brought and as the equipment and supplies for field work were bulky and difficult to transport, it was found quite impossible to secure the necessary carriers to take all at one trip, so that plans were made to establish camps from time to time and have the material brought in by relays. The trail for about 2 miles led through an open, flat, semicultivated region and shortly after leaving the coast we were obliged to ford the Subaan River, a stream of considerable size. At the end of 2 miles the trail left the level land and crossed a broad, interrupted ridge, densely forested with magnificent trees and broken by ravines containing small streams, some tributary to the Subaan River, others to the Binabay. The highest altitude reached on this ridge was about 1,000 feet. We established our first camp where the trail crossed the Binabay River at a distance of about 6 miles from Subaan and at an altitude of 700 feet, making it with some American miners who had located a placer claim in the stream bed as coarse gold to a limited extent is found in the sand.

On November 3 the carriers were sent back to Subaan for more supplies and the other members of the party reconnoitered for trails in the vicinity leading towards Halcon, climbing to the top of the ridge to the southwest to an altitude of 1,200 feet. At the top of this ridge we entered the first Mangyan clearing and here saw the only representatives of these people who were encountered on the entire trip.

Three small houses, each consisting of a platform raised 2 to 3 feet from the ground, with a thin roof of palm leaves, but without walls, were located in this clearing, and later, along the ridge a short distance to the southwest, a larger house was found. All the houses were deserted on our arrival in the clearing, but on the return trip, in the first house we found an old man and his son, who told us that his family had fled at our approach, but that when he saw there were white men in the party he had returned. These people were all small in size, being about 4 feet 10 inches in height, their hair was short and curly.

From the opening which we had reached we secured a magnificent view of Halcon to the south, while the coast region and Calapan were visible to the east. We found two trails leading down to the Alag River, one from the southeast corner of the clearing and the other from the south side. The latter, being more in the direction of Halcon Peak, was selected for our route. On November 5, our carriers having arrived from Subaan the day before, we left the Binabay River and on arrival in the clearing mentioned above again encountered the old Mangyan who said that he was too old to act as our guide, but that he could secure for us one who knew the trails. As a guide familiar with the routes leading to Halcon would have greatly facilitated our work, he was asked to procure one, but after waiting about an hour we decided that he had no intention of returning and so we went on to the Alag River. The trail was well defined, leading down a 30° to 45°, well forested slope. Just before we reached the Alag the path crossed a tributary stream of considerable size which offered no difficulties in fording and as none of our natives had a name for it, we christened it the Egbert River in memory of the late General Harry V. Egbert, United States Army. The distance from the Binabay River to the Alag was about 2 miles. At the point where the trail reached the Alag, the stream was about 100 yards wide, not very deep but quite swift and from the place where we first forded the stream to an altitude of 1,200 feet, where we made our last crossing in the ascent, we found no still water whatever. The American miners living on the Binabay informed us that during the previous ten days there had been comparatively little rain and accordingly we found the Alag fordable. An attempt was made to cross it at the junction of the Egbert River, but it was found to be too swift and deep at that point and we were obliged to proceed up the stream for several hundred yards and then to follow an indirect course along the bars in the more shallow water. It was necessary to ford the stream several times during the day's march in order to avoid abrupt bluffs and cliffs. The Alag, at a distance of about 1 mile above the junction of the Egbert, divides into two nearly equal branches; one, flowing from the direction of the Halcon Range was considered to represent the main stream and the other, being unknown to any of our party, was named Whitehead River in honor of the late John Whitehead, an English naturalist who made the first serious attempt to ascend Halcon.

From the entrance of the Egbert River to that of the Whitehead, the Alag flows through a rather wide valley lying between two low, densely forested ridges, the river in this interval being from 50 to 100 yards wide. Our trail followed the margin of the stream, sometimes on one side, sometimes on the other. However, after passing the entrance of the Whitehead River the banks of the stream became very irregular, its bed being much narrower, so that because of the corresponding increasing difficulties in fording it was found advantageous to travel through the underbrush along a bench about 25 feet above the level of the stream. This necessitated slow progress as we were obliged to cut a trail through the dense vegetation. Continuing on up the Alag for a short distance above the junction of the Whitehead River, Camp Number Two was established late in the afternoon. On November 6 and 7 the carriers were sent back to Subaan for further supplies and the remainder of the party reconnoitered up the Alag. The river cañon was found to be very narrow, with perpendicular cliffs sometimes several hundred feet in height and covered with dense vegetation, which often rose abruptly from the bed of the stream. In searching for the most feasible route for our carriers the banks were climbed at intervals, but in no case could a view be secured because of the dense thickets. It was decided that the only practicable course, for the present at least, was along the bed of the stream. The advance was rendered very difficult because of the narrowness of the cañon and the swiftness of the water which made fording impossible in most places; moreover, we were aware of the fact that the river was subject to sudden and enormous floods and that in case of heavy rains we were almost certain to be cut off from our base of supplies. The tremendous force of the water in times of floods was much in evidence as we traveled upstream; great water-worn bowlders, 6 to 15 feet in diameter, were everywhere encountered and in places large caverns had been cut in the solid cliffs by the action of the water. At a distance of about a mile above Camp Number Two and at an altitude of 900 feet, another smaller river joins the Alag from the east, this we named the Bolton, in memory of the late Lieut. Edward C. Bolton, former Governor of the District of Davao, Mindanao. This was undoubtedly the stream which Lieutenant Lee's party followed in crossing the divide between the Alag and Bagbaujan Rivers in April, 1904. A beautiful cascade about 15 feet in height exists just below the junction of this with the Alag, here the whole volume of the river is forced through a narrow passage between two large bowlders, falling into a pool surrounded by high cliffs.

On November 8, with twenty loaded carriers, we broke camp and proceeded up the stream to the junction of the Bolton River. Here, finding it no longer possible to follow the Alag, it was decided to take the ridge between it and the Bolton which, however, was exceedingly steep and covered with dense forests. No trail was to be found and accordingly one had to be cleared as we advanced. Ascending to an altitude or 2,250 feet, we came into a deserted Mangyan clearing and before us, across the valley of the Alag, was a magnificent panorama of the entire Halcon Range. Progress during this day had been exceedingly slow because of the difficulties encountered in proceeding along the Alag and in ascending the ridge, it being necessary to limit our speed to that of our loaded carriers. Late in the afternoon it was found that we had convered a distance of but approximately 1½ miles. It was then decided to establish Camp Number Three in the Mangyan clearing, with a subsidiary base camp at the junction of the Alag and Bolton Rivers and consequently natives were sent out to locate water and a messenger was despatched on the trail to instruct our scouts to establish a base camp at the place indicated and to build grass houses of sufficient size to accommodate all of our carriers who were to be traveling back and forth bringing supplies. Just before dark our natives reported "no water" and we prepared for a dry camp, when a brisk shower came on which enabled us to catch enough water for our immediate needs on the tent fly and ponchos. Early on the following morning our natives located a small stream tributary to the Bolton River at several hundred feet below our camp.

As many essential supplies remained at Subaan and at various points along the trail, most of the carriers were sent back to the coast, and from November 9 to 11 the country was explored for trails or for a feasible route to the main range of Halcon. At first it was thought that the best one would be by way of the ridge which we were then on, and that by following this we could avoid descending into the cañon of the Alag. Two of the party followed the ridge to the southwest of our camp for some distance, attaining an altitude of 3,500 feet. Although they found that it might be possible to gain the main range by this route, such a course would necessitate a long detour in order to pass the Alag and practically every foot of the distance would be gained only by trail cutting of the most difficult kind through the dense ridge thickets. In the meantime others of the party reconnoitered in the direction of Halcon peak, finding a well-defined Mangyan trail leading to the Alag at some distance from our camp. On November 12, some of our carriers having returned the night before, we left the camp in charge of two natives and proceeded with thirteen loaded carriers along the Mangyan trail to the Alag. The slope was very steep, being 60° to 70°, and after descending about 1,000 feet we reached the bottom of the cañon at a point where two streams of equal magnitude joined. Here we found that the Mangyans, in order to be independent of the river in times of flood, had constructed a suspension bridge across the cañon. This was about 75 feet long, made of seven rattan stems so arranged that the lower three strands formed a foot bridge, the upper two serving as hand rails. On both sides of the cañon these rattans were firmly attached to large trees and on the west bank they passed over a huge bowlder in order to give the span sufficient altitude above the water in times of flood.

The west branch was considered to represent the main stream, and the fork flowing from the direction of Halcon Peak was named the Halcon River. The party crossed the Alag, some by means of the suspension bridge, others by fording; the trail was found to continue on up the opposite bank, undoubtedly leading to a recent clearing of considerable magnitude which was plainly to be seen from our Camp Number Three and from which it did not appear feasible to ascend Halcon. Accordingly, we crossed the Halcon River, taking the ridge between it and the Alag, continuing until we reached an altitude of about 3,200 feet, under the impression that we were on the ridge leading to the main range. Late in the afternoon it was discovered that we had still another cañon to cross, and as our carriers were exhausted, we established Camp Number Four in the forest, without water other than the small supply which we had in our canteens and such meager amounts as could be secured from freshly cut rattan stems.

Striking camp at daybreak on the 13th, we proceeded along the ridge for a short distance when we reached a deserted clearing; passing through this we entered a more recent and occupied one which was several hundred acres in area, where one or two deserted houses were found. About one and one-half hours after this we reached the cañon between us and the main ridge, crossing it near its head. The stream in this cañon was called the Cuming River in honor of Hugh Cuming, an Englishman who made extensive collections of plants and animals in the Philippines between the years 1836 and 1840. Breakfast was prepared at this point and at about 10 o'clock we were again on the march, proceeding up the steep eastern bank of the Cuming River, following a rather indistinct Mangyan trail. Near the top of the ridge we entered a deserted clearing containing the ruins of an old house, where the trail seemed to end. From this point a course was taken up the crest of the ridge, which here was rather broad, although it gradually narrowed as we ascended and we soon found ourselves forced to cut our way through exceedingly dense thickets up an 80° slope. After much difficulty we attained the summit of a small spur covered with dense, characteristic, mossy forest. As it was late in the afternoon when the crest line was reached, Camp Number Five was established on the narrow bench in the dense forest, just below the top of the ridge, a small stream being located about one-fourth of a mile distant and 300 feet below. The distance covered in this day was only about one and one-half miles. On November 14 the carriers were sent back to the base camp on the Alag River for further supplies and on this and the following day trails were opened up on the ridge to an altitude of 7,000 feet, and a point at an altitude of 6,300 feet was selected for Camp Number Six.

Trail cutting became progressively more laborious as we advanced, because of the increasingly stunted character of the vegetation. No particular difficulties were encountered in the first mile, the trail being opened just below the crest of the ridge, but beyond this point further progress was found to be impossible because of a perpendicular landslide which was in our path, making it necessary for us to force our way through the exceedingly dense thickets up a very steep slope to the top of the ridge, the summit of which was attained at an altitude of about 6,650 feet. This ridge was found to slope gradually upward and it varied from 5 to 30 feet in width, in most parts breaking abruptly on both sides in nearly perpendicular slopes. The crest line forest was composed of stunted trees with short, stout trunks and stiff branches, often semiprostrate, and with large spreading roots raised more or less above the ground. Intermixed with the trees was a heavy stand of shrubs and bushes, while an abundance of the very spiny rattans, and nearly as spiny smilax, clambering everywhere through the thickets, rendering trail cutting always a difficult operation and frequently a painful one as well. Everywhere the ground and the trunks and branches of the trees were covered with thick masses of yellow and green moss, filmy ferns, numerous orchids and other epiphytic plants, the ground mat often being one foot or more in thickness, composed of mosses, lichens, ferns and herbaceous plants. A trail was cleared along this ridge to the foot of the sharp slope at an altitude of about 7,000 feet.

We had been favored with exceptionally good weather up to this time, only an occasional shower interfering with our progress, causing no greater inconvenience than a more or less thorough wetting of our persons, which was of minor importance as we were wet nearly every day in fording streams. However, on reaching an altitude of 4,500 feet we entered the region of practically constant fogs and rains which made traveling exceedingly unpleasant because of the wet thickets and heavy drip from the leaves even when it was not raining, as well as because of the reduced temperature, the thermometer rarely registering above 60° F.

We established Camp Number Six on November 17 at an altitude of 6,300 feet at a point previously selected and at a short distance below where our trail ascended to the crest of the ridge. No running water was to be found within a half mile of the camp, but the practically constant rain which prevailed for the thirteen succeeding days rendered the distance from running water of secondary importance. The slopes on the north were very precipitous and in many places entirely denuded of soil and vegetation, where extensive portions of the main ridge had slid into the valley. The land slides, some of them of recent origin, present a bare, rocky face, covered only in places with a scant growth of grass, herbaceous plants and small bushes. We secured a magnificent, view of Halcon, which was 1½ miles distant across a deep valley, by cutting out a few trees on the steep slopes below our camp, but the peak was very rarely visible because of the prevailing fog and rain. Occasionally at intervals of cessation in the severe storm which now came on, the wind would drive the fog away. Judging from these glimpses it became very evident to us that from our present position the only route leading to the latter was by way of the ridge on which we were. On November 18 our carriers came in from Subaan, having made the trip from the coast in three and one-half days. Some were retained for work about the camp, some were sent back to the base camp at the junction of the Baco and Alag Rivers to remain there until further orders, while others were returned to Subaan to bring in food to supply the party on the trip back to the coast. The ones whom we retained at Camp Number Six suffered much from the cold and dampness, as also did the Americans in the party.

Realizing that our food supply was limited and that, because of the present storm, the Alag would be unfordable and accordingly no further supplies could be brought in, it was deemed unwise to remain in camp hoping for a change in weather, hence, on the morning of November 19, Mr. Hutchinson and I proceeded by way of the ridge to an altitude of 7,000 feet where previously we had cleared a trail. We continued it up the steep slope, attaining the main ridge at an altitude of 7,800 feet; the one leading to Halcon Peak running from the east to the west at about right angles to our ridge trail. The montane brush of the upper ridges became reduced to an open heath commencing at the crest line and extending for some distance down the southern slope, the ground cover consisting of tufted grasses, with only occasionally scattered stunted bushes and shrubs, a most grateful change from the dense, mossy ridge thickets through which previously we had been obliged to cut trails. However, these heath lands were limited in extent and so we passed rapidly through them and found the succeeding ridge thickets to be very much more dense than those farther down. Progress through them was literally foot by foot and then only by constant use of bolo. The heavy rain which had set in a few days before, still continued without cessation, adding to our discomfort, the temperature being constantly below 15° C. Owing to the low temperature, the high wind and the continual rain, our position was exceedingly uncomfortable and at times of especially heavy downpours the warmth of our bodies did not suffice to keep the temperature of our wet clothes up to a degree of comfort, the occassional, heavy bursts of cold rain cooling the body to such an extent that, even with the very active and arduous work of trail clearing in the dense thickets, our sufferings from cold were greatly accentuated. At times, as we came to the crest line, the cold wind would add to our discomfort, although much of the time we were fortunately sheltered from it by the dense thickets. Pitcher plants (*Nepenthes*) became very abundant, clambering everywhere in the thickets, so that in cutting our way through the underbrush, at frequent intervals our bolo slashes would upset the equilibrium of from one to a half dozen pitchers, each holding one-half quart or more of water, which would be precipitated upon us. These irregular douches were far more disagreeable than the constant shower bath from the falling rain.

The heath lands on the upper ridges were interrupted by deep ravines, filled with very dense vegetation through which progress was exceedingly slow. Unfortunately for us, these heath lands were very limited in area and we soon came to a dense ridge thicket which we afterwards learned continued uninterruptedly to the summit of the highest peak. Along this ridge we cleared a narrow trail to an altitude of about 8,300 feet. As it was then late in the afternoon and with the heavy rain still continuing, we returned to camp, arriving just after dark. On November 20 the storm was much more severe than it had been on the preceding days and we were obliged to remain in camp, having little to do other than to listen to the constant drip of the rain and the roar of the streams in the valley below and wondering about the state of the Alag and the safety of our base camp. On the following day the heavy rain continued through the morning, but it slackened at midday, so that we left Camp Number Six at noon and proceeded up to the main ridge, making Camp Number Seven on the open heath at an altitude of 7,900 feet, carrying with us a tent fly and blankets, as well as food for three days. The carriers employed in transporting the material to the high ridge were immediately sent back to Camp Number Six. Light rains continued during the afternoon's march, but toward evening the clouds lifted somewhat, giving us an indistinct view to the south and west. The country south was much more open than that to the north, many of the slopes being grass covered instead of forested, and a number of Mangyan houses were to be seen below 4,000 feet. The entire country toward the south, so far as could be seen, was very rough and mountainous, but the ocean was visible to the southwest; no view to the east and north could be obtained owing to the fogs and clouds. At the point where we pitched our tent a well-defined Mangyan trail crossed the main ridge from north to south, apparently leading up by way of the cañon of the Halcon River or by one of its tributaries, or from one of the Mangyan clearings which we did not visit. As the trail was a much traveled one it seems probable that there is considerable communication between the people living to the north and to the south of Halcon. Evidently, these

Mangyans do not possess the usual superstitions regarding mountains which are found among most natives of the Philippines, or at least not to such a degree as to prevent them from ascending the high ridges. Just before dark the heavy storm set in again, continuing all night and throughout the following day. In spite of it, we left camp on the morning of November 22 with the object of reaching the highest point on Halcon. In passing from the point where we stopped trail cutting a few days before, to the summit of the mountain, we encountered the densest thickets seen on the entire trip, and immediately below the peak it took two men three and one-half hours of constant and heavy work with bolos to open a very narrow trail, for a distance of less than one-half a mile. At 1 o'clock in the afternoon of November 22, twenty-one days from the coast, the party reached the highest point on Halcon. The summit being shrouded in clouds, no view was obtained and as all the members of the party where suffering severely from the cold and rain, we stopped only long enough to take aneroid readings and to deposit a record of the trip, which was placed in a sealed bottle and secured to the largest tree on the summit, there being no bowlders available of which to build a cairn. The top of Halcon is a somewhat flattened ridge about one-eighth of a mile long, sloping gradually to the southeast; the peak is covered with a dense growth of stunted trees, none of them more than 10 feet in height, the ground and the trunks, branches and even smaller branchlets of the trees being thinkly covered with from 5 to 15 inches of moss.

No marks of a trail were observed and no signs were seen anywhere in the vicinity of the peak which would indicate that the summit had ever been visited by human beings, and it would be physically impossible for any person to reach it through the dense forest growth without leaving signs of trail cutting. Late in the afternoon the party arrived at Camp Number Seven and spent a most disagreeable night in wet clothes and blankets, as it was impossible to start a fire because of the continuous wind and rain and consequently no warm food could be prepared. On the morning of November 23 we returned to Camp Number Six and during the two following days we were obliged to remain there because of the storm. On the morning of November 26, our carriers who had remained at the base camp at the junction of the Alag and Bolton Rivers, came back reporting the Alag River very high and unfordable, and for that reason the carriers who had been sent to Subaan had been unable to return; moreover, the food supply at the base camp was very low. As we had no further object in remaining at the higher altitudes we broke Camp Number Six on the morning of November 26 with the intention of sleeping that night at the large Mangyan house described on page 182. As we had but few carriers, every member of the party was obliged to pack a heavy load. The topographer and hospital corps man left Camp Number Six about half an hour before the remainder of the party, but on our arrival at the Mangyan house they were not to be found, having apparently lost the trail, nor did they appear that night.

On the following day, with the Mangyan house as headquarters, search was made on the back trail for the missing men and messengers were sent down to the Alag River to see if they had arrived at the base camp. No trace of them was found on this day and on the 28th the search was continued. In the morning word was received that they had not appeared at the base camp and accordingly a party was detailed to make a more thorough search on the back trail. However, in the afternoon the lost men appeared in the Mangyan clearing. It seems that on coming down the ridge from Camp Number Six they had missed the trail crossing the headwaters of the Cuming River, and had proceeded for some distance down the main ridge leading toward the Halcon before discovering their mistake. Thinking it possible that they could easily reach the Alag at the point where the suspension bridge crossed the cañon, they continued on down the ridge, but where unable to reach the stream because of the steep cliffs. Accordingly, they retraced their steps for some distance and found an old Mangyan trail which they followed for some time, crossing the Halcon by a second suspension bridge and again attempting to reach the Alag and follow it to the junction of the Bolton River, but once more, because of the dense thickets and high cliffs, they were obliged to give up the attempt. Finally, they retraced their steps by the main ridge, located the trail crossing the headwaters of the Cuming River, and arrived at the Mangyan house after having been out nearly three days without other food than a few acorns which they found in the forest. While we were searching for this party on the ridges, they were in the cañons attempting to reach the streams and accordingly did not hear our shouts or shots.

Because of the weak condition of the men who had been lost, no further progress was made until December 1, except to concentrate our supplies and equipment at Camp Number Nine, at the point where the Bolton River joints the Alag. The Alag was still high and unfordable, although the water was about six feet below the point at which it had been a few days before. All members of the party had been on short rations for several days and there seemed to be no immediate prospect of further supplies reaching us from the coast. On the afternoon of November 30 a rude bridge was built across the Alag at Camp Number Nine by felling trees and floating the trunks down stream so that they lodged against bowlders in the bed of the river, the ends of the trunks being lashed in place with rattan and a hand-rail was added. A brisk rain in the night caused the river to rise considerably and one-half of the bridge was carried away, so that we had to replace it on the following morning. On December 1, the first clear day after thirteen days and nights of nearly constant rain, we broke Camp Number Nine and moved all the material across the river, but as we had with us only seven carriers, a temporary camp was established on the opposite bank and the two American soldiers, who were still in a weak condition, were left in charge.

At noon, the remaining members of the party, all heavily loaded, proceeded down the east bank of the Alag. Many difficulties were encountered during the afternoon. In a number of places where bluffs arose abruptly from the stream and which on the up trip we had been able to avoid by fording the river, we were now obliged to climb, fording being entirely out of the question. These frequent detours entailed extensive trail cutting which, with a 50-pound pack, soon became a decidedly painful operation, especially as in order to find a feasible route we had frequently to climb the steep banks or to follow the nearly as steep ravines to a height of two or three hundred feet or more. Camp was made just after dark at the foot of a bluff on the edge of the river. A daybreak on December 2 we proceeded down the stream to a point opposite the entrance of the Egbert River, where Camp Number Ten was established.

All the carriers were immediately sent up the river to bring down more supplies, a scout, who succeeded in crossing the Alag with some difficulty, went into Subaan for additional ones, and one man was sent to the Binabay River for food. Fortunately for us the weather still continued clear and the Alag fell rapidly. On December 3 the carriers were again dispatched up the Alag to bring down the remaining equipment, returning to camp late in the afternoon, the two soldiers accompanying them and at the same time the bearers from Subaan arrived, reporting that they had encountered serious difficulties in crossing the Alag on the trip back to the coast, but that they had finally reached their destination and started back with supplies. On their return, finding that the river was high and that it was impossible to cross, they remained on the north bank of the stream for three days waiting for the waters to subside, and then returned to Subaan. As the carriers came in late in the afternoon it was impossible for us to move camp across the river on that day. A heavy rain came on in the night which caused us considerable anxiety for the reason that if it continued for any length of time, we should be unable to cross the river on the following day and would be obliged to follow the stream down to tide-water along the south bank.

The rain continued throughout the night and at daybreak we found that the water had risen about six inches, so that the stream was still fordable, although with great difficulty and considerable danger. Heavily loaded carriers with the assistance of one or two men without loads could usually keep their footing, but some of them were carried downstream by the current, wetting some of our equipment. The Americans in the party who attempted to cross without loads, depending entirely on heavy poles for assistance, were invariably carried down by the current and were obliged to swim the last few yards in the very swift water. After many delays and heavy work all the equipment was taken across the river and transported to the top of the ridge between the Alag and Binabay Rivers, where Camp Number Eleven was established. The party made an early start on the morning of December 5 and proceeded by way of the Binabay to Subaan, arriving there about 2 o'clock in the afternoon. We were obliged to remain in Subaan throughout the following day and 4 o'clock on the morning of December 7 embarked for Calapan on a large sailing banca, arriving at noon. On the night of December 9, after forty days, the party returned to Manila, having accomplished the objects of the trip.

GENERAL OBSERVATIONS.

No data are available regarding the rainfall in Mindoro but judging solely from the vegetation in the southern part of the Island, the rainfall there is much less and the dry season much more prolonged than it is in the North, in the vicinity of Halcon. The presence of this high mountain and its subsidiary ranges causes an enormous precipitation, extending continuously over nine months of the year, from May to January, while the so-called dry months, February, March and April, are not always completely so, as is to be seen from the heavy rain encountered by Lieutenant Lee in April, 1904. During most of the year the mountain is shrouded in fogs and is very rarely entirely free from clouds for any extended period. The fact that the rivers flowing from the Halcon Range, although comparatively short, carry an enormous body of water and that they are subject to great and frequent floods, as both our party and Whitehead learned from experience, would indicate an abnormally heavy rainfall. The vegetation of Halcon, not only that of the higher altitudes, but of the lowlands surrounding the mountain and extending even to the coast at Baco, demonstrates a high and practically uninterrupted humidity throughout the year. Abundant epiphytes, ferns, orchids and other plants and especially the filmy ferms, which are dependent upon a high and constant humidity for their existence and are identical with, or similar to the species on other mountains in the Philippines at altitudes above 3,000 feet, are found in the vicinity of Halcon, sometimes at sea level. In the forests along the rivers at as low an elevation as 250 feet such plants are abundant and many species are represented.

Halcon is covered with and surrounded by the most dense forests excepting where the vegetation has been destroyed by the Mangyans. From the limits of cultivated land along the coast, extending inward and up to an altitude of 3,000 feet, the trees are of large size and would prove to be of considerable commercial value for timber if the question of transportation were a more simple one. Beginning at an altitude of about

1,200 feet on the ridge between the Alag and Binabay and at about 5 or 6 miles from the nearest Tagalog settlements, one finds traces of the Mangyans in clearings, occupied or deserted. It is the custom of these people to clear a given area by chopping down the trees and brush and after burning it over they plant upland rice, corn, and other crops. Such clearings will be occupied for one or more years until the soil shows signs of exhaustion, until the slopes are denuded by erosion or until the exuberent tropical vegetation becomes too great an obstacle to the primitive agriculturist. He then clears another piece of ground and the deserted one soon reverts to its former forested condition. After a term of years the same land may be cleared again by the same methods. Everywhere on the more gentle slopes from the Binabay River to an altitude of 3,500 feet on Halcon, we observed clearings in all stages, from those freshly cut and not yet burned to those in cultivation, and from those recently deserted to clearings in all stages of reversion to forest. Some of these were very extensive and must have entailed a great amount of labor, for many of the trees felled were 3 feet in diameter, and the only tools possessed by the Mangyans are working bolos and very small, narrow axes.

From a forestry standpoint, practically all the forests in the immediate vicinity of Halcon have been ruined by the above methods of clearing, for it seems evident that the Mangyan selects virgin woods for his work of destruction, doubtless because he has found from experience that the soil is better than in those localities where he has previously cleared and which have reverted.

The floristic conditions[10] of the lower forests indicate high and continuous humidity, shown by the numerous ferns, mosses and epiphytes. As higher altitudes are reached these epiphytes become progressively more abundant, until on the exposed crest-line ridges, beginning at 4,000 feet, the trees are found to be completely covered with a dense mass of mosses and epiphytes, so thick and close that frequently the bark of the tree is not visible. The character of the vegetation entirely changes, the constituent species of the lower forests disappear and others totally different in aspect take their place. Various species of oak and one species of maple are abundant at intermediate altitudes, but on the ridges the vegetation is largely characterized by certain species found in such habitats throughout Malaya. Epiphytic ferns and orchids and other plants become more plentiful and there is a greater diversity in species; mosses are much thicker and more luxuriant, enwrapping even the branches and branchlets of the trees and forming a deep, soft, soil cover, frequently a foot in thickness. Epiphytic shrubs and vines are abundant and give an added character to the vegetation; rhododendrons, huckleberries, raspberries and other plants characteristic of the more temperate regions made their appearance, and the pitcher plant (*Nephenthes*), becomes common, climbing through the thickets. The vegetation again gradually changes above 4,000 feet, the trees and shrubs become more stunted and dwarfed, epiphytes increase in abundance, peat moss appears in the ground cover and many of the constituent species of trees, shrubs, herbaceous plants, epiphytes, etc., are again quite different from the ones at 4,000 feet. On gaining the high, main ridge, at 7,800 feet, there is a most radical change; the montane brush has become reduced to a mere heath over considerable areas, the ground having a thin cover of grasses with scattered, stunted bushes and shrubs, a curious mixture of north-temperate and Australian types. These heath lands disappear along the ridge towards the high peak and the montane brush is again in evidence, but more stunted and much more dense than on the lower ridges; epiphytic orchids and ferns become reduced to few species and there is a corresponding increase in the abundance and density of the mosses and lichens which everywhere cover the ground and trunks of the brush. Small branches, even no larger than the finger, appear to be 6 inches or more in thickness owing to their dense covering of yellow and green moss. These upper thickets represent the densest vegetation I have ever observed in the Philippines. It was almost impossible to penetrate it even with a liberal use of the bolo.

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[10] For an account of the Flora of Mount Halcon see Merrill, *this Journal C. Botany* (1907), **2**, 251.

CONCLUSION.

The origin of most of the mountains in the Philippines is due to volcanic activity, but Halcon is radically distinct from the others in structure. It is a mass of granite, white quartz, schist and marble. Iron pyrites was observed in some localities, while gold in small amounts is found in the sands of the streams flowing from it. Slate was observed by Mr. McCaskey a short distance north of the main range. In general structure, so far as can be determined from descriptions to be obtained, Halcon seems geologically to be the same as Mount Kinabalu, British North Borneo, the highest peak in the Malayan region.

Halcon Range is a fold, the main ridge running in a generally east and west direction, irregular in profile, but continuous for a long distance at high altitudes. So far as could be determined, three great ridges radiate from the main range, one to the west, one to the south and one to the east, while to the north especially, the slopes are very precipitous and show several subsidiary spurs.

Mindoro itself is anomalous in some respects as compared with other islands of the Philippine group, but later when more definite knowledge is secured regarding it and its neighbors, it may be shown that it is really the oldest part of the Archipelago proper. The one large mammal found in the Philippines, *Bubalus mindorensis,* said to be most closely related to a Celebes form, is confined to the Island of Mindoro; certain genera of lowland plants, such as *Antiaris, Chrysophyllum, Ochthocharis,* etc., characteristic of the Malayan region in the west and south, are known in the Philippines only from Mindoro, while the plants from the higher altitudes on Halcon show remarkable affinities with those known from Mount Kinabalu, North Borneo, in many cases they are of specific identity and encountered only in the two localities. At the same time there is a remarkable number of Australian types present in the Halcon flora. From the geological, botanical and zoölogical evidence at hand, indications are found which would seem to point to an early land connection between Mindoro and some great mass to the west and south, but at the same time there is shown a prolonged separation and apparently a greater age than has been discovered in any other part of the Philippines proper. It is probable that Mindoro, in the various disturbances which have from time to time submerged portions of the Archipelago, has constantly remained above the sea.

Extensive collections of natural history specimens were made on the trip, but most of the material was collected and prepared under the most adverse conditions. A series of papers based on this matter, which will add much to our knowledge of the fauna and flora of the Philippines is planned.

A feasible route to the mountain was discovered and mapped, and it was proved that Halcon could be ascended even at the most unfavorable season of the year. The course of the Alag River was in part determined and charted, this large stream not being shown at all on many maps of the Philippines. Several of its tributaries were located and named.

To anyone contemplating a like trip on Halcon the following recommendations will prove to be of some value, and will apply as well to many other mountains in the Philippines. Brown soap should be issued regularly to the native carriers to be used as a leech repellent. This is smeared on the bare legs once or several times a day if necessary, for the loss of blood from the attacks of leeches is always considerable, and serious complications which might cripple a party in regard to transportation might arise from a resulting infection, for on Halcon the only feasible method of transportation is by carriers. All members of the party wearing shoes should be equipped with woolen puttees instead of leather or canvas leggings, as the former are proof against the attacks of leeches, while the two latter give no protection whatever. Eyeholes on shoes should be smeared with soap each day. Quinine should be issued regularly to the members of the party to guard against outbreaks of malaria. All supplies needed on the entire trip should be carried, as no food can be secured in the interior of Mindoro, at least on the north of the Halcon Range, except a few very poor *camotes,* and some small game such as birds, rats and monkeys, the latter two generally not being considered acceptable food. If one is not limited as to time, doubtless the best carriers for such a trip as we took would be the Mangyans, but they can be approached only with difficulty and because of their superstitions can not be relied upon to stay with a party. As carriers are very difficult to secure in Mindoro and do not prove satisfactory even when they are found, they should be secured at some point in Luzon and landed with the party making the ascent. Camp outfit and equipment should be made as light as possible and food should be confined to essentials. All food supplies and equipment should be wrapped in waterproof packages; the packs should be adapted to carriers and should not exceed 40 or 50 pounds in weight for the ordinary carrier.

The proper time for ascending Halcon, judging from our imperfect knowledge of the rainfall in the vicinity of the mountain, is in the months of February, March, April, and May, but these months are by no means dry, as is shown by Lieutenant Lee's experience north of Halcon in April. During the remaining months of the year heavy rains prevail, and anyone penetrating beyond the Alag River on our route would do so at the constant risk of being cut off from his base of supplies, as in reality happened to our party. To be cut off for any extended period in the interior of Mindoro would be in most cases a very serious complication and every precaution should be taken to avoid it.

My acknowledgment and thanks are due to Major J. K. Thompson, United States Army, for the accompanying map and for the copies of Lieutenant Lee's report; and to Major George P. Ahern, Director of Forestry of the Philippine Islands, for copies of Lieutenant Jenning's and Foresters Merritt's and Hutchinson's reports.

ILLUSTRATION.

Plate I. Sketch map of route taken by exploring expedition from Calapan to summit of Mount Halcon, Mindoro, P. I.

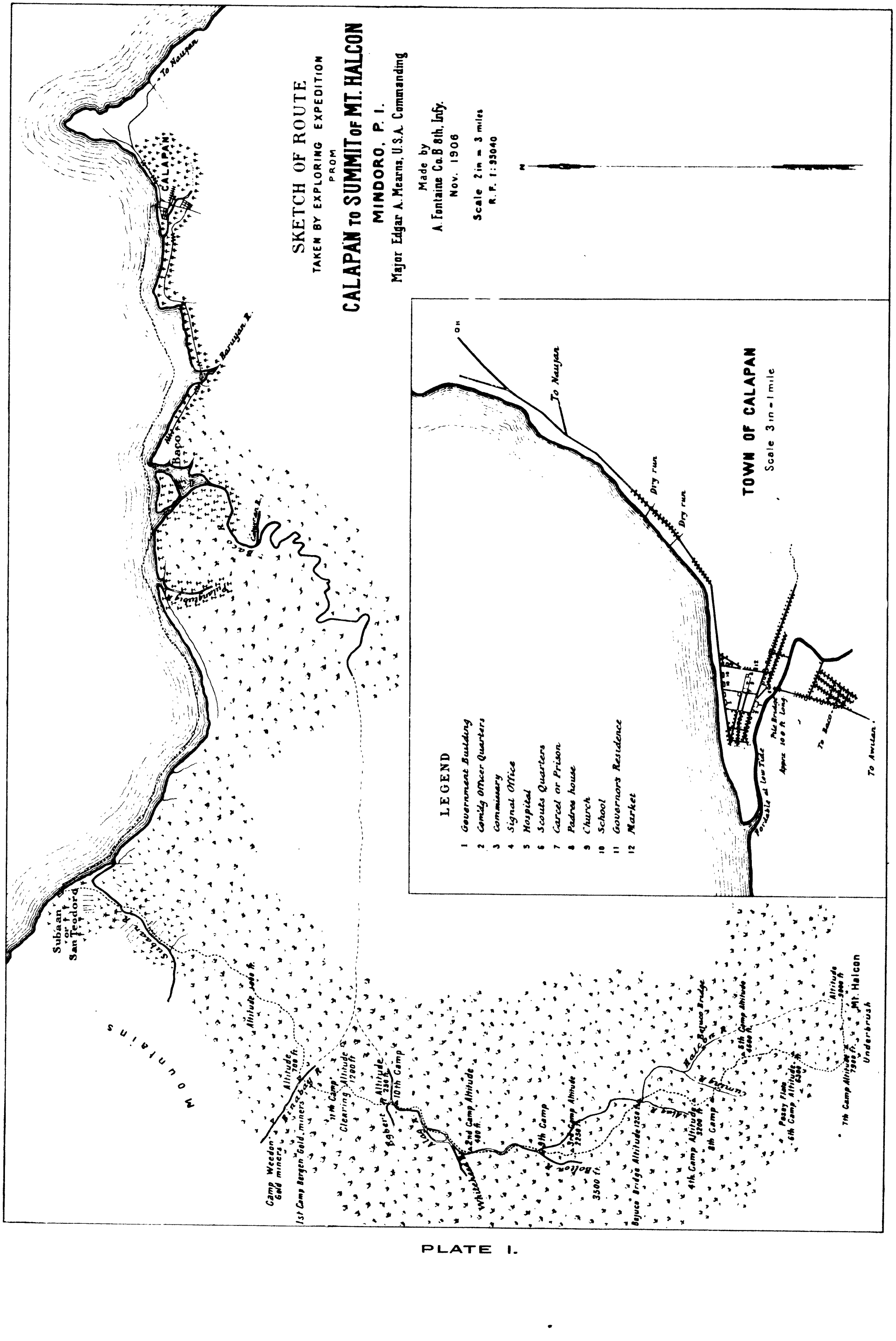
SKETCH OF ROUTE
TAKEN BY EXPLORING EXPEDITION
FROM
CALAPAN TO SUMMIT OF MT. HALCON
MINDORO, P. I.
Major Edgar A. Mearns, U.S.A. Commanding
Made by
A. Fontaine Co. B 8th. Infy.
Nov. 1906
Scale 2 in = 3 miles
R. F. 1:95040
N
TOWN OF CALAPAN
Scale 3 in = 1 mile
LEGEND
1 Government Building
2 Comdg Officer Quarters
3 Commissary
4 Signal Office
5 Hospital
6 Scouts Quarters
7 Carcel or Prison
8 Padres house
9 Church
10 School
11 Governors Residence
12 Market
To Naujan
Dry run
Dry run
Pile Bridge Approx 100 ft long
Fordable at low tide
To Baco
Calapan
Baco
Subaan or San Teodoro
Mountains
Altitude 1000 ft.
Camp Weedon Gold miners
1st Camp Bergen Gold miners
Altitude 700 ft.
Binabay R.
11th Camp
Clearing Altitude 1200 ft
Altitude 750 ft
10th Camp
Bgbert R.
Alag R.
Whitehead
2nd Camp Altitude 400 ft.
9th Camp
3rd Camp Altitude 2250 ft.
Bollon R.
3500 ft.
Bejuco Bridge Altitude 1250 ft.
Alag R.
4th Camp Altitude 3200 ft.
8th Camp
Halcon R.
Bejuco Bridge
5th Camp Altitude 4600 ft.
Posey Flats
6th Camp Altitude 6300 ft.
7th Camp Altitude 7900 ft.
Altitude 9000 ft
Mt. Halcon
Underbrush

PLATE I.

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NOTES ON THE GEOLOGY AND GEOGRAPHY OF THE BAGUIO MINERAL DISTRICT.

By A. J. EVELAND.

(*From the Division of Mines, Bureau of Science, Manila.*)

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INTRODUCTORY.

Benguet and some portions of adjacent northern Luzon have been visited and explored by numerous scientists and travelers and in addition to the interest which the region and its inhabitants have aroused, the undoubted occurrence of gold, apparently in considerable quantity throughout the region, has increased the desire for more knowledge of this part of the Philippine Islands.

Almost since the day when Spain released the Islands to the United States, prospecting and development of the mineral resources of the country has gone on and confidence in its value has steadily increased. With that confidence, active operations have gradually expanded and at this date, the mineral wealth of the Philippines seems to be assured. The Benguet district in particular may be ranked as one of the most promising of the Islands.

The investigation of which this report is the result was begun by me in April, 1905, and attention was first turned to a topographic map of as much territory as seemed to be under immediate development. Mapping was carried on over the area covered by mineral claims and this ground was extended also to take in that area in which the study of the geologic and related problems would seem to have a bearing on the purely economic questions involved. With the assistance of one American and occasionally a few Igorots, the map work was completed by the beginning of the rainy season in June. The area embraces about 100 square miles including, in addition to the work of the writer, a survey of the Bued River cañon, made by Major *L. W. V. Kennon,* United States Army, when he was in charge of the construction of the Benguet road; and a topographic survey of the immediate vicinity of Baguio by Mr. *G. H. Guerdrum,* assistant engineer of the Bureau of Public Works, in charge of Baguio surveys.

Stadia work with a transit based on a system of triangulation of the most prominent points and checked by traverses and rapid reconnaissance methods such as were consistent with the accuracy required, were employed to accomplish the work in as short a time as possible. The map, which is published with the report, includes the region between Mount Santo Tomás on the west and the limit of mining or prospecting operations on the east; from near Trinidad on the north to a little south of Kias or "Camp Four" of the Benguet road on the south. In November, 1905, the field work was resumed and the investigation of the geology and mines taken up during a field season of four months.

The latter work, which I carried out alone, only using native labor in transporting specimens, etc., was undertaken first with headquarters at

Baguio, from which point at least the more elevated portions of the area could be reached by aid of a horse. A general geologic reconnaissance of the district extending beyond the mapped area, in order fully to grasp certain broader problems was followed by a more detailed study of the geologic relations of the smaller area. The perhaps extraordinary occurrence and sequence of geologic phenomena in so limited an area made this portion of the work extremely interesting, and, needless to add, correspondingly difficult.

Within a comparatively limited field, the study of recent vulcanism reveals lava flows of different ages, igneous intrusions of notable extent and the still active evidence of numerous hot springs; ore deposits are encountered of undoubted value and extent, varying in type from free milling gold ores to "basic" gold-bearing sulphides of copper, lead, zinc and iron; sedimentary beds with a rich fauna can be seen, the study of which may be vitally important to broader questions of the former extent of the Philippine Islands, or rather their connection with continental areas; rarely can such a combination be found, both as to the interest to the scientist and the value of knowledge to be gained from an economic standpoint.

With the information acquired by me, the way was clear to a closer study of smaller areas from a purely economic basis. It was possible by camping at the different places where prospecting and mining operations were going on thoroughly to examine every opening of importance. Ores and veins were inspected, faults measured—in short, all that was necessary was done to attain the total of information, so far as it might be derived from the present stage of the district in mine development. Numerous samplings and assays aided in the work, and in addition some underground surveys were made where vein structure or dislocation made it advisable.

In the field, excepting in rare instances, every assistance and coöperation was met with. The natives, miners and others with whom it was necessary and desirable to come in contact made smooth many rough paths, and this brief acknowledgment of those courtesies and aids may be taken as but a fraction of the appreciation of the writer.

It is a pleasure to record the aid of my colleague Mr. W. D. Smith in determining and classifying the fossil remains of this region while I was studying and working on field material during the preparation of this report, and in that connection no little coöperation was rendered by him in aiding me to an understanding of the paleontology and the petrography of the region; this will be spoken of later. I also desire to express my appreciation of three weeks' assistance in the field given me by Mr. Smith.

GEOGRAPHY.

POSITION.

As has already been stated, the area mapped and discussed in this report embraces about 100 square miles, of which Baguio, although near the northern boundary of the area, is the logical center. From Baguio radiate such roads as the region possesses, and like any other, the development of transportation precedes or parallels development along all other lines.

Baguio is the seat of government of the entire Province of Benguet; its location is given in the Gazetteer of the Philippine Islands for 1902 as approximately in longitude 120° 38′ 50″ E. and in latitude 16° 32′ N. Later observations give exact figures as latitude 16° 24′ 27.14″ N. and longitude 120° 36′ 6.9″ E., making the site of Baguio somewhat less than 150 miles almost due north of Manila.

TRANSPORTATION.

Baguio is reached from Manila from both the south and the west, as will be seen by reference to the map showing transportation routes of the region. At present, Dagupan is the "farthest north" as far as rail transportation from Manila is concerned, but preliminary work is well advanced for the continuation of the railroad through to Camp One on the Benguet road. The western coast of Luzon is also marked by a railroad route, and a few years more will see it in operation. From the western coast and the foothills at Camp One, a horse trail and an automobile road respectively terminate at Baguio. The mineral region lies to the east of the Benguet road and that region will be spoken of in this report from now on as the "Baguio district." Prospecting or mining has been done to a more limited extent outside of this area and so little definite information has been gathered, that for all purposes "Benguet," as the miner speaks of it, is translated into the plateau region extending easterly from the eastern slope of Mount Santo Tomás and lying partly on the elevated plateau or ridge which is a portion of a northwest-southeast range of considerable extent, and for the remainder and greater part including the headwaters of those rivers which have cut laterally and transversely into the main mountain mass.

In this region transportation is generally by trail. On the upper and more level portion of the area, and especially in the vicinity of Baguio, considerable road work has been done. Between La Trinidad and Baguio a good wagon road has been constructed, the southern continuation of which has been carried to Loacan and the Copper King mine. A wagon road has been built to Bua from Baguio over which the Benguet Consolidated Mining Company hauled the mill recently installed. In the region set apart for a summer colony near Baguio, numerous drives have been laid out.

Well-graded horse trails have been constructed from Kias to Baguio, around the east flank of Kias Ridge, and from Bua to Itogon. There is some form of trail between all the pueblos and barrios of the district, and the present governor of the province is carrying on excellent work in the construction of new and the repair of old lines of communication.

Freight for Baguio can be handled via steamer to San Fernando, on the west coast of Luzon, and thence to Baguio over part of the distance (to Naguilián) by road and the remainder by pack train, a total distance of about 25 miles from the coast; or, as at present, via rail to Dagupan and from Dagupan to Baguio over the Benguet road. The distance from Dagupan to Baguio via the Benguet road is 53.54 miles, of which the distance to Camp One is 26.2 miles over flat grass country. The construction from Camp One on is that which has attracted considerable attention, principally because of its high cost—$75,000 per mile, or a total of about $2,500,000 to the date of nominal completion.

The first survey of this road was made late in 1900 and an estimate of $75,000 for cost of construction given. Various causes contributed to the delay in completion and the increased cost, and it was not until January, 1905, that it was possible to make the through trip on wheels. As many as 2,500 laborers of almost every nationality were employed at one time on the construction work, native Filipino labor being extensively used. An elevation from sea level at Dagupan, and a slight elevation at Camp One, to 4,800 feet at Baguio is gained in its 50 miles of length with an actual maximum grade of 10 per cent. Whatever the cost (and although maintenance costs will be heavy) the road supports traffic and furnishes the only real highway to the Baguio district.

The route from Baguio to San Fernando is perfectly feasible for cheap wagon-road construction and when the coast railroad is completed to the latter point, the coast route may seriously compete with the Benguet road either by wagon or railroad extension. Present freight rates from Manila to Baguio are as below:

Manila to Dagupan, rail, 41 cents (Philippine currency) per 100 pounds.
Dagupan to Baguio, wagon 3½ cents (Philippine currency) per pound.
Manila to San Fernando, steamer, ₱6 per ton of 40 cubic feet.
San Fernando to Baguio, packing, estimated ₱3 per 100 pounds.

The cheaper route is, therefore, via Dagupan, and of course it is quicker. Passengers can go through in twelve hours from Manila via rail and automobile. The railroad to Camp One will cut time and prices, and beyond occasional washouts, etc., which are to be expected, the Baguio district will at the close of 1907 have a reliable and rapid method of communication with Manila.

From Baguio, the transportation problem is one of small magnitude. The Copper King region is reached by an almost level wagon road which needs little expense for maintenance. Bua is reached by a wagon road of a maximum grade of 6 per cent, and trails and roads to the Antamok and Gold Creek region are easy and cheap of construction and maintenance if properly located and built in the beginning. Wagon transportation is perfectly feasible to any part of the mineral district. Repairs will not be excessive, provided proper ditching is done and culvert work is constructed and the torrential rains of the summer are taken into account; and such small bridge work as is necessary can be done cheaply with the abundant standing timber and cheap native labor.

CLIMATE.

The climate of this region has been much discussed because of the proposed use of Baguio as a summer capital, and as a convalescing station for the United States Army, Navy, and the Civil Government employees of the Philippine Islands. Briefly summarized, from various reports of the Weather Bureau, the following may be stated:

The temperature, taken at Baguio and representative of all the Baguio plateau, is on the average consistently lower than that registered at Manila by 7° C., the difference ranging between 7° and 9° C. throughout the year, as is shown by the following table, which is a plot of the temperature variations at Baguio and Manila, recorded during 1900 and 1901.

The daily variation ranges from 2.4° C. to 8.7° C., the changes being quite in inverse proportion to the rainfall and increased cloudiness.

Variation of the temperature at Baguio and Manila for the years 1900 to 1901.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Manila	25.25	25.15	26.7	28.4	29	28.3	27.5	26.9	27.5	27.2	26.5	25.4
Baguio	17.45	16.8	19.35	21.35	20.15	19.5	19.15	18.15	19.4	19.6	18.9	17.95
Difference	7.80	8.35	7.35	7.05	8.95	8.80	8.35	8.75	8.1	7.6	7.6	7.45

The minimum temperature both in Manila and in Benguet is reached in February, with a second minimum in August, due to the extraordinary rainfall which occurs in that month. From February a steady rise occurs, which culminates in a maximum of about 29° C. in April, the warmest month, followed by a steady decline to the end of the year, only broken by the August depression, with a reaction of about one degree in September.

The annual rainfall, considerably more important than the temperature, amounting to over 100 inches per annum, places the Baguio district under the classification of the regions of abundant rainfall. The year is divided more or less distinctly into a dry and a rainy season. The salubrious climate of the region, at least during the dry season from February up to and including June, is principally due to the rainfall conditions. As there is no high land on the east and south, the prevailing winds during these months, from the west and southwest, cause a moderate rainfall, thereby reducing the temperature during March, April, May, and June.

PLATE I. TYPICAL TIMBER STAND ON BAGUIO PLATEAU.

Rainfall for 1900–1901 at Baguio, in millimeters.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.49	14.46	37.08	8.11	102.11	318.52	391.93	940.33	288.66	125.70	64.00	138.77

Total, 2,431.16 millimeters = 96.23 inches.

During the same period the rainfall at Manila amounted to an average of 1,986 millimeters.

From September, 1902, to August, 1903, observations were as below:

Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
602.7	212.1	75.9	24.1	5.1	0.0	16.5	97.0	131.8	168.4	760.8	767.9

Total, 2,862.3 millimeters = 112.77 inches.

Care in road construction is one of the principal necessities caused by rainfalls of such magnitudes as are recorded, and the drainage in the streams creates a problem of control to be considered wherever water power is used. During the rainy season, and especially after one of the heavy rains of a few hours' duration, where 20 inches or more may be recorded in a day, streams which have been but threads of water become rivers of great velocity and power for harm.

VEGETATION AND TIMBER.

Open grass land and areas of pine timber constitute almost all of the Baguio district, with the grass lands predominating; an almost insignificant percentage of agricultural lands also exists. A thick stand of cogon grass of 2 or 3 feet or more in height, which is burned during the dry season, is on the open grass land, and these areas are the cattle ranges of the country.

The timber is practically all pine, of one species (*Pinus insularis* Endl.); it resembles the loblolly pine of the southern United States very closely in size, form, rate of growth and character of wood; when it is on the upper slopes and ridges in more open and exposed stands, it is very similar to the western United States yellow pine. The forest is quite open, with heavier growths along streams, north slopes and other sheltered locations. Here the timber attains its best height and growth. Some hard wood occurs, but it is negligible in amount, except on the summit and west slopes of Mount Santo Tomás.

The timber will average about 100 feet in height and in diameter 21 inches, giving a merchantable length of 57 feet, with four logs with a yield of about 550 to 750 board feet per tree, or as measured on a given area, a cut of about 2,300 feet per acre, the entire stand amounting to 7,500 feet per acre.

One company has been taking out timber for local use with a small mill and native labor; the wood which up to the present has been used for building construction was of sapwood (*Alburnum*) and unseasoned; it has shrunk and warped badly, but it is believed that with proper seasoning it will give satisfaction. The sapwood, yellow white in color like the loblolly pine, rots too readily in contact with the ground, but the light, red-brown heartwood, is more durable it is frequently very resinous, and when so, is practically indestructible.

For mining purposes, there is sufficient timber within every distance to satisfy demands for some time to come for a camp of moderate size, and with a greater growth of the mineral industry, logging can keep pace with development at a reasonable expenditure.

Agriculture in the district is confined to a very small area and only a sufficient amount for local consumption is produced.

The population of the Baguio district proper only embraces two or three barrios of small size. Benguet Province has a population (census of 1903) of 22,745, of which 917 are civilized and 21,929 "wild;" that is, Igorots. The civilized population which is congregated almost entirely in Baguio and La Trinidad, consists of Ilocanos, with a sprinkling of other coast races. The total population, of which about one-half or approximately 11,000 are males, with possibly another 9,000 from surrounding provinces, represents a body of not over 20,000 males to draw on for possible labor. "Possible" is used advisedly, for of this number, because of condition, location, aversion to work, etc., it is not believed that more than several thousand are to be considered in any way as "probable" labor. The Igorot of these parts at least is a mild-mannered brown man, small in stature, but well endowed physically, whose wants are infinitesimal. Experience with him as a laborer has demonstrated his usefulness to a degree. A considerable number of the race are quite familiar with crude mining operations and are fair workers underground. They are fairly intelligent, peaceable and good, natured, and when for some cause they are driven to labor, are—in view of their low rate of wage (25 cents, gold, per day) and efficiency—satisfactory, unskilled laborers. Anything beyond that can not be looked for and moreover there are but few of them who will remain in employment for any length of time.

HYDROGRAPHY.

Probable nowhere in the Philippine Islands is the work of rain and running water so clearly indicated as in the Baguio district and vicinity. Changes take place in the surface of the area; drainage shifts, and the topography alters almost visibly from day to day. The drainage of the region is noteworthy.

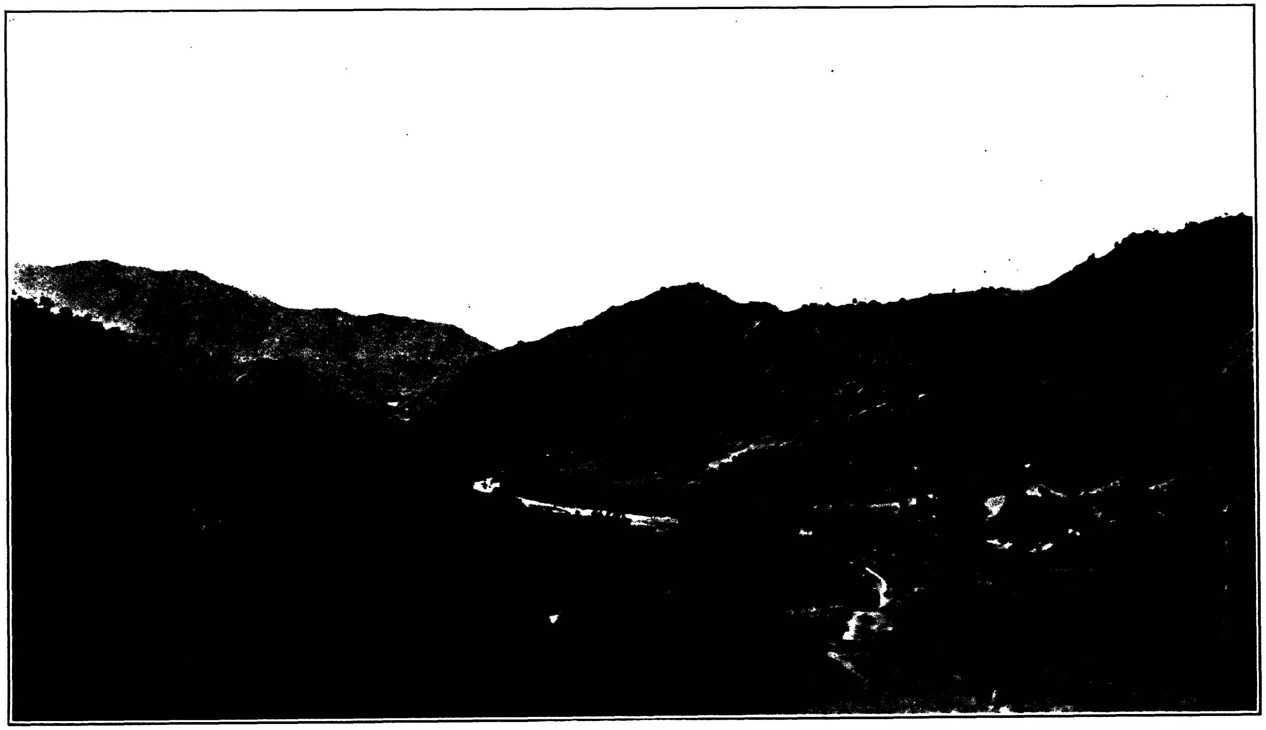

PLATE II. AGNO RIVER VALLEY NORTH OF AMBUKLAO.

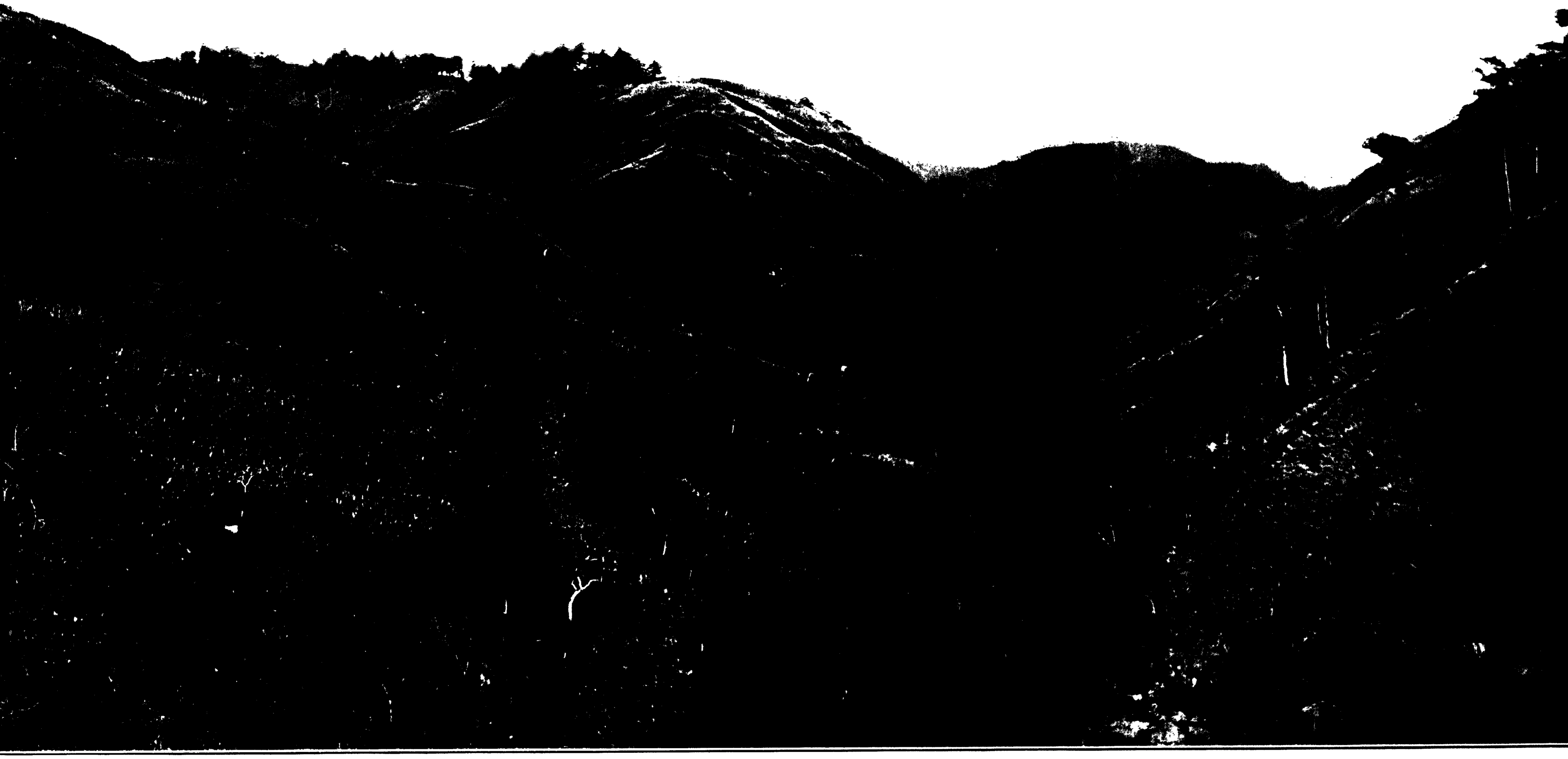

PLATE III. THE ANTAMOK RIVER VALLEY.

DRAINAGE.

Although the Agno, the largest river of the Province of Benguet, is beyond the border of the district to the east, it has an important bearing on the drainage. The headwaters of this river are on the eastern flank of Mount Datá, the divide between southern Lepanto and northeastern Benguet, and in its passage south to the plains of Pangasinan it gathers the run off from the western slopes of the main mountain range, the *Cordillera Central*, the backbone of Luzon, and the eastern slopes of the smaller range and ridge which forks southwesterly from Datá and terminates at Santo Tomás, forming the Benguet highland. Therefore, it gathers meteoric waters over a comparatively large area, and erosion by it and its tributaries has been considerable. All the drainage from the eastern half of the Baguio district feeds into one branch, the Itogon.

The Antamok River drains the smaller valley east of the Pakdal-Itogon Ridge; it is quite dissimilar to the rest of the drainage in that it possesses no tributaries of any magnitude. Although the valley has been deeply incised, no lateral streams have kept pace with it within the map limits. At its headwaters east of Pakdal there is more or less of a basin of auxiliary drainage; at Bua, one small western branch is developed, and east of Antamok a somewhat larger branch to the north has cut into the eastern wall of the valley, but erosion has generally been confined to the main valley. Some rough measurements on the Antamok in the dry season gave the quantity of water flowing as 1,200 cubic feet per minute, or 20 second-feet. Power is being taken from the river at this point for use in a stamp-mill and developed by pipe line and impulse wheel.

A short distance below Antamok, the Antamok River joins the Itogon, of which it is a lateral tributary. The Itogon drains the area from the Pakdal-Itogon Ridge to the Kias Ridge, through several good-sized streams and through the Sile or Gold Creek, the Batwaan and many smaller streams. Gold Creek has the larger territory, heading in the eastern and southern sides of the Baguio Plateau and reaching the Kias Ridge with its eastern branches. Its volume normally is greater than that of the Antamok, and throughout its area the lateral branches have kept pace with the erosion of the main channel, cutting a well-defined basin between the Kias and the Pakdal-Itogon Ridges.

The Batuaan heads in the southern end of the Kias Ridge and again resembles the Antamok in its clean-cut valley with little lateral extension. The system described above constitutes the drainage of the larger and eastern part of the Baguio district.

The Baguio Plateau is drained to the north and west directly to the China Sea, via the Irisan and Trinidad Rivers, which in the Baguio district proper are mere creeks, cutting slight valleys in the plateau.

Their work has been different from the erosion of the southern portion of the area and except for the drainage purpose they serve, they are unimportant. This will be further discussed under physiography.

On the western side of the Baguio-Kias Ridge, the Bued, or Moti River is the channel through which drainage proceeds. The origin of the Bued is not far from Baguio, on the plateau, and after collecting the waters of the elevated regions, it cuts its way, between Mount Santo Tomás and the Kias Ridge, south to the plains. Laterals tributaries are numerous, and some of them, like the Balatok Creek at Kias and the large tributary (the Quisat, in the native dialect) coming in east of the crest of Santo Tomás, have in erosion almost kept pace with the main stream. The Bued River cañon is the most noteworthy in the district. Cut in a gentle reversed curve from the edge of the Baguio Plateau to the debouchement on the plain below at Caoriugan, and in depth over 2,000 feet to the bed of the stream, this gorge is opened up by the Benguet road on its lower slopes, where formerly travel was well-nigh impossible, the old Igorot trails being on the ridges on either side.

Viewed from the standpoint of possible water supply, the region is well watered, even in the dry season. Numerous large and pure streams, enough to supply a population as numerous as will probably ever occur on the Baguio Plateau, exist there. The district throughout is well supplied with potable water, and, although by the arbitrary map boundaries, certain hot springs do not fall within its lines, it may be well to mention them.

MINERAL SPRINGS.

Large sulphur springs which have been used for ages for medicinal purposes by both natives and others in the country are found in the lower part of the Bued River cañon, a half mile or so below Balongabong or Twin Peaks, on the west bank of the river. These springs have a temperature of about 50° C. and are distinctly sulphurous. Other smaller and similar springs may be noticed at various places along the river above.

On the Itogon River just outside of the eastern boundary of the map of the district accompanying this paper, is a group of hot mineral springs which have formed deposits of considerable extent. The water in these has a temperature of about 86° C. and in several of them distinct geyser action, with an intermittent flow of some force, is noticeable. The springs are saline and some of them contain sulphuretted hydrogen gas. The most noteworthy constituents of the water, by analysis, are: carbonic acid gas, sodium chloride, sodium and calcium sulphates, silica, calcium and iron bicarbonates and nitrogen, a total of about 2.5 grams of salt in solution in a liter. The spring is claimed to be very beneficial for medicinal purposes and it could well be utilized by proper construction, as it is less than 10 miles from Baguio.

North of the Baguio district, at Tublay, hot springs also exist of the same general character, but slightly lower in temperature (70° C.) and containing a smaller amount of salts in solution. Iron springs, now apparently quiet, have left large deposits in the vicinity of Bua, and in various other localities hot-spring action is plainly indicated.

The northern part of Benguet Province is particularly richly endowed with mineral springs, hot and cold, and the geology of this and adjacent regions clearly indicates, geologically speaking, the evidence of only recent vulcanism, or more strictly, its final and dying phenomena.

PHYSIOGRAPHY AND TOPOGRAPHY.

The Baguio district—that is, the region covered by the topographic map accompanying this paper—is a small portion of a part of northern Luzon, with which it is very closely connected and of which it is representative; it so happens that this small region is immediately on one of the main tectonic axes of the Philippine Islands, and hence of the Malayan Archipelago. The *Cordillera del Norte* situated a few miles to the east of Baguio is the main axis, at least of the western half of northern Luzon. The mountain system of Benguet, on the southern end of which the Baguio district is located, is only one of the many ramifications of this master axis, which has its origin on the east side of southern Luzon and which may safely be continued to east Mindanao. This major axis is probably one of the original tectonic axes of the Asiatic Continent, formed by the wrinkling of the more plastic crust of the earth as the globe has contracted. In it the oldest of the Philippine rocks are found and on it all of the agencies of construction and destruction have been at work since the Philippine Islands, as such, originated.

Throughout the Province of Benguet there runs a subsidiary chain, the two ends of which are established by Mount Datá on the north and by Mount Santo Tomás on the south; this range, or more strictly speaking, this ridge, describes a curve, concave to the east.

The Agno River, cutting its valley, which originally was a purely tectonic depression, between the Benguet Ridge and its main trunk, the *Cordillera,* has incised its main valley so deeply and has, by erosion of its tributaries over its catch basin, removed such an amount of material to the plains lying toward the south, that the Benguet Ridge stands out as a mountain range, small but fully developed, between the coastal plain along the China Sea and the *Cordillera Central del Norte,* the backbone of Luzon, with a large valley, that of the Agno River, separating them. The mountain region of Benguet then, of which the Baguio district is representative, is of this simple type. It represents no diastrophic change of the earth's crust, as the "block" type of mountains in which huge blocks of strata have been uplifted along a fault plane and tilted into prominence, as is the case in the southern

Oregon (United States) ranges and is true of other parts of the Great Basin region of the United States, nor does it represent the folded type of which the Alps are the most familiar example; huge folds and overturns of strata like crumplings of so much paper. The strata covering the east and west flanks of the Philippine mountain areas have been gently raised and broken, leaving the ends of the arch on either side, but a part of this tilting was due to the formation of the sea deposits on the already inclined floor of the mass where the ridge has been produced; moreover there has only been comparatively gentle arching.

PHYSIOGRAPHIC DISTRICTS.

Beginning with a small region which locally represents such a simple type of elevated country, there is developed within it four distinct physiographic types:

(1) The mountain region.
(2) The elevated plateau.
(3) The intermediate uplands.
(4) The incised-valley system.

THE MOUNTAIN REGION.

The mountain region is barely represented. The eminence of Pakdal is a remnant, no doubt, of the original ridge which ran north at an elevation of probably over 6,000 feet, to join the higher region of northern Benguet. It stands up from the eastern edge of the Baguio Plateau to a height of about 5,500 feet, and though seen from the west its elevation is not particularly noteworthy, the absence of the plateau on the east reveals the height of this region in the drop-off to the valley of the Antamok River and in the unobstructed view of the Agno Valley and the main *Cordillera* to the east from the top of the ridge.

Mount Santo Tomás on the other hand is a part of the "mountain region," but it is so only because of its height. It is not, as is Pakdal, a remnant of the former configuration. Santo Tomás is a block mountain of the faulted type and it is locally developed, being the only instance of such development in the Baguio district. A fault scarp of about 1,500 feet marks the northeastern slope, which is closer to a vertical than to a horizontal plane. The tilting of this large block of sedimentaries is plainly to be seen from the Bued River side of the Baguio Plateau and the corner of the block—the crest of Santo Tomás—at 7,342 feet above sea level, is as sharply defined as it could be pictured. Because Santo Tomás is on the edge of the plateau the height is more apparent from the south and west, where the slopes of the mountain run down to the coastal plain. From the plateau side, where there is a difference of elevation of less than 2,500 feet, this height is not as noticeable.

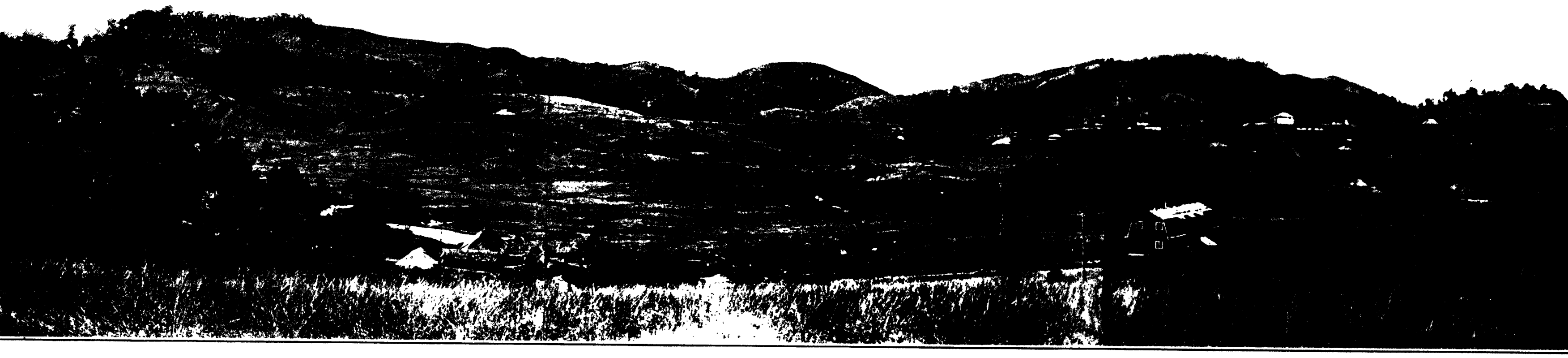

PLATE IV. BAGUIO.

Typical mountain topography prevails on both these eminences (Santo Tomás being included, although abnormal). There is but little good water, almost none in fact, at these elevations, standing as they do clear of all the surrounding country; consequently all erosion is a direct result of the very considerable rainfall of 100 to 120 inches per annum. Denudation has been rapid, especially on Santo Tomás and deep scars have been cut into its flanks by the erosion of the streams carrying the run-off. All the streams are naturally far above base level, and deep, V-shaped gorges represent the type of stream beds. While frost is rare here, the difference in temperature is sufficiently great, no doubt, somewhat to aid in the disintegration of the rocks. Steep slopes prevail, and talus is carried away by the excessive erosion, so that sharpness of outline continues to exist.

THE ELEVATED PLATEAU.

The Baguio Plateau is the most striking of the four physiographic types of the region. It is a peneplain of limited extent, with an average elevation of about 5,000 feet and with a drainage and topography so characteristic of a lowland region, that, viewed from a central point where the valleys of the Bued and Agno River drainage are not visible, it is hard to realize the situation of the area.

The drainage is not deeply marked and there is plain evidence of much shifting of divides and valleys. Only small streams prevail over the region and except for transitional border areas where gradients are increased very rapidly before the streams drop off into the deeper valleys, the erosion has not been great in stream beds. Baguio proper drains to the north into the Irisan and Trinidad Rivers. The Pakdal area divides its drainage between the north, uniting with that from Baguio, and the southeast, draining into the deeper valley of the Agno tributaries. There are no streams of any size in this portion of the district and the large rainfall seems to be partly added to the ground water and partly run off in numerous small channels, rather than through any well defined system.

South of Baguio and Pakdal the drainage is to the east and west of the Baguio-Kias Ridge, into both the Bued and Agno waterways. The topography is of a mature type over the entire region. Low, rounded hills with gentle slopes, graded valleys with low gradients and in part winding streams which show some small amount of rejuvenation in the more deeply cut valleys exist, but they have not altered the serpentine course they followed originally. The stream draining Baguio affords one instance of this character. It is a barely noticeable brook from the divide where it originates up to a ponding which occurs south of Baguio; the softer rock materials here have yielded to erosion and the stream, although formerly large and flowing directly from the depression through a now deserted wind gap to the north, has barely sufficient gradient to join the Pakdal drainage to the east of Baguio, where a small, well-defined valley, with slopes and a gradient out of all proportion to the remainder of the drainage back of it, joins with a second flattened area north of Baguio. From this it finally escapes into the Trinidad River.

The headwaters of the Pakdal are merely rivulets which follow such valleys as they have themselves been able to cut during the seasonal rains, and in many instances the shifting of the local divide for a few feet has resulted in the capture of adjacent streams and the abandonment of the older channels.

The Pias Valley is more marked and although it is relatively of small size, it has rounded out a fairly mature existence before it drops off into the Bued River channel west of Laoacan. At Laoacan another old valley, now devoted to the cultivation of rice and which has a small stream flowing through it, is evidently a relic of the former drainage of the region. This valley is mature and almost devoid of running water; at its mouth it drops off through a declivity of almost a thousand feet to the valley of the Bued River.

The drainage of the whole plateau is striking in that in itself it exhibits every evidence of maturity and that only the corrasion of the near and the more powerful superimposed drainage has thrown it into relief, at an elevation of 5,000 feet and over.

THE INTERMEDIATE UPLANDS.

The intermediate uplands are represented by the drainage of the Bued and Agno River tributaries. The elevation of these regions ranges from 2,500 to 4,500 feet, and as they are evidently confined to one period, they are normal in every particular; with the valleys of the Antamok, Batuaan and Gold Rivers and their total drainage area, the intermediate uplands and the valleys they constitute one region, all lying to the east of the Baguio-Kias Ridge. A comprehensive view of the region from either the Pakdal or Kias elevation shows that the central valley, namely that of the Gold River, is the more mature. The Antamok and Batuaan streams have confined their work to the cutting of steep-walled valleys with few lateral tributaries; their slopes are steep, with a gradient generally of over 30°, and both streams maintain a fairly direct course. Their headwaters are basin-like in character and in these situations erosion is pronounced. The Gold River has been widened to a greater extent by lateral tributaries, and it presents a valley broad enough and sufficiently graded to support several small villages with their attendant industries, agriculture and the raising of cattle.

PLATE V. LAOACAN, SANTO TOMÁS IN THE BACKGROUND.

PLATE VI. VALLEY OF THE ANTAMOK RIVER BELOW ANTAMOK.

PLATE VII. BUED RIVER VALLEY.

PLATE VIII. LOWER SLOPES OF THE BUED RIVER AT KIAS.

THE INCISED VALLEY SYSTEM.

As has been stated before, the Bued Valley is noteworthy for its beauty and grandeur. Its side slopes will average much over 30° and in that portion of it covered by the map, it gains an elevation of from 2,000 to 5,000 feet. In the transverse section there is evidence of several stages of deepening and at Kias there is pronounced evidence of recent uplift, tilting from the south; nowhere is the V-shaped gorge sufficiently wide at is bottom, nor sufficiently gentle of slope to support more than an Igorot hut or two, and it is only since the construction of the Benguet road along the valley that it has been the scene of human activity. Hanging valleys are common along its course and the entire evidence of topographic forms tends to the conclusion that the drainage has been of more recent origin than that of the Baguio Plateau. It is especially evident that this is the case where lateral gorges enter the main valley, and at the southern end of the valley the present stream is cutting at a rapid rate vertically into its V-shaped cañon.

GEOLOGY.

GENERAL.

Although the Baguio district is but small in area, there are involved in it geological problems almost too broad and complex to be within the scope of this reconnaissance. Such data as have been gathered, and which will have to serve until a study may be made of a more extended field, will be subject to greater or less modifications in the light of future work. Beginning with the oldest rocks, we have a basal mass composed of dioritic rocks which can be correlated with, and evidently is, an integral part of the dioritic base exposed in Lepanto and in other northern provinces of Luzon. Excepting certain local variations of composition and texture, these two rocks are petrographically identical, and the stratigraphic evidence is all on the side of the hypothesis of a dioritic igneous core, of at least this one (Luzon) of the Philippine Islands. It has been taken for granted by a number of the few who have heretofore written on Philippine geology on such evidence as was available, that the hidden core of the Philippine group would eventually be found to consist of crystalline schists upon which post-Tertiary sedimentaries have been laid down and to which mass the neo-volcanics have been added, but so far, at least in northern Luzon, the areas seen have uniformly exhibited a massive dioritic base. Becker[1] has carefully summarized all the occurrences of schists and older rocks of the

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[1] Report on the geology of the Philippine Islands, *U. S. G. S. 21st. Ann. Rep.* (1899–1900).

Archipelago which were known at the time his paper was written, and while he points out that there may be a more or less close connection between the Philippine group and Borneo on lithologic grounds, he admits that there is no inconsistency in Abella's view [2] that the dioritic rocks represent the oldest of the Philippine series, if those schists of similar composition are included under the head of "dioritic rocks." It is a pleasure to record in the results of work even so little detailed as that given in the present paper, data which coincide with the deductions of Mr. Becker, who had only vicarious observations of varying reliability to serve as criteria and also with the observations of Abella, who, although limited in his scope of work, has proved, for the most part, to be the most trustworthy of the workers in this field.

BASAL MASS.

There seems then to be good ground for believing that the diorite I have observed in the Baguio district represents the starting point of our Philippine geology, at least for northern Luzon. I have described it in a former paper,[3] discussing its appearance in Lepanto; it occurs over a large area of the present Benguet field; various observers have noted it over a sufficiently large portion of Luzon; and Abella in particular has verified his field notes with the microscope in order to justify the above hypothesis.

In the Baguio district the exposures of the basal diorite, as would naturally be supposed, are generally most prominent at the lower elevations, although on the western border of the area, the most prominent exposure is the highest point in the district, namely the crest of Mount Santo Tomás. Here the rock is light green in color, finely grained, holocrystalline to the eye, hard and compact, with apparently little weathering. Plagioclase and amphibole may be distinguished with a lens, together with some chlorite and occasional quartz and magnetite crystals. The valley of the Antamok River shows the best exposures of this diorite and it is here most typical of the large area.

The rock megascopically is dark green, holocrystalline, massive; it is very hard and apparently more resistant to erosion than any other rock in the district. Only plagioclase, amphibole and a dark-green chloritic mineral can be distinguished with the eye. Locally, over a small area, the amphibole is developed to a greater extent. At one of the tunnels of the Bua Mining Company, the main cross-cut to the "main reef," the porphyritic nature of the rock, which has amphiboles sometimes measuring 15 millimeters in length, is very evident. In connection with the development of the amphiboles, the almost universal quartzose nature of the rock is less evident or entirely wanting—no quartz can be seen with the eye or with a hand lens. Under the microscope the normal phase of the basal diorite presents a granitic or a pan-idiomorphic granular structure. In almost all the sections examined much saussuritization has taken place and the resultant minerals are variable in different localities. The structure is plainly that of a plutonic rock and there is evidence of slow cooling, the first crystallization taking place being that of the feldspars. Certain sections show porphyritic facies and the mass is evidently variable. The plagioclase feldspars show polysynthetic twinning, and in these sections they are probably near the lime end of the series, calcite being pronounced. Possible intergrowths of feldspars are noticed. Measurement of extinction angles on different sections in some cases gives labradorite (observed on Carlsbad twins); other sections at right angles to the albite twinning gave 31° to 33° as extinction angles. A slide occasionally shows anorthite, and a sample of the rock from the valley of the river Sili exhibits andesine.

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[2] Abella: Apuntes físicos y geológicos (1884), 30.

[3] Eveland: Preliminary Reconnaissance of the Mancayan-Suyoc Mineral Region. *Bull. Min. Bur.*, Manila (1905), 4.

The feldspars are much decomposed, and calcite, zeolites, epidote, and chlorite are present in varying amounts. The ferro-magnesium minerals generally are too much decomposed to show more than outline of faces, but from occasional fresher sections they are clearly determined to be pyroxenes. Actinolite has evidently been a constituent of prominence, although hornblende more nearly represents the average composition.

Magnetite is present in large amount, over 10 per cent being present in some sections, and it, and chlorite developed in light-green flakes and strings throughout the slides, are most prominent.

Although it is apparently a basal mass the diorite has been through other processes than mere crystallization from the magma. The microscopic aspect of samples from certain localities seems to point to a granulation and recrystallization of the original rock, and in view of the neovolcanics which are so prominent over the area, some metamorphism is to be expected. There is enough evidence in the numerous slides examined to make it certain that, although basal in position, the diorite is not, strictly speaking, representative of a deep-seated igneous mass. It shows variation of structure and composition identical with those exhibited by an extrusive and although subsequent alteration may be, and probably is, responsible for many of these variations, it seems to be a more justifiable hypothesis that the diorite, although now it is stratigraphically the basal mass of Luzon, at the time of its origin was, in part at least, extrusive and intrusive in relation to some still older formation of which, so far, no trace has been seen. Five analyses of samples of the diorite from various localities are as follows:

Analyses of the Benguet diorite.[4]

Constituent.	I.	II.	III.	IV.	V.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture at 110° (M—110°)	0.37	0.32	0.46	0.16	0.18
Loss on ignition (M+110°)	3.16	3.54	3.24	.75	3.24
Silica (SiO_2)	49.89	51.08	49.20	51.48	50.71
Alumina (Al_2O_3)	1.87	1.47	3.64	20.31	4.74
Ferric oxide (Fe_2O_3)	2.61	3.57	.84	6.24	2.26
Ferrous oxide (FeO)	23.47	25.30	25.00	3.46	20.64
Calcium oxide (CaO)	10.75	8.15	10.66	8.86	13.48
Magnesium oxide (MgO)	6.57	4.12	6.76	4.29	4.21
Potassium oxide (K_2O)	.09	.22	.06	2.07	.18
Sodium oxide (Na_2O)	2.01	2.13	.76	3.01	1.03
Total	100.79	99.90	100.62	100.63	100.27

Number I represents the porphyritic variety from the "Middle Reef."

Numbers II, III, are from the Antamok River.

Number IV is from Gold Creek.

These analyses should be compared with the following ones, made on samples from the Lepanto area on specimens of the "Mancayan diorite" which probably were fresher:

Analyses of the Mancayan diorite.[5]

Constituent.	I.	II.	III.	IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture (—110°)	0.50	0.28	0.38	0.12
Loss on ignition (+110°)	2.74	1.38	.70	2.26
SiO_2	50.67	51.00	47.98	47.94
Al_2O_3	21.21	18.01	18.94	21.96
Fe_2O_3	11.31	.23	7.08	2.48
FeO	.21	9.31	3.98	3.42
CaO	6.86	8.89	11.01	12.63
MgO	4.10	6.53	7.06	6.83
K_2O	.10	.46	.44	.19
Na_2O	1.41	4.42	2.56	1.49
Total	99.11	100.51	100.13	99.35

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[4] Analyses Numbers I, II, III and V are by Dr. R. F. Bacon, and Number IV is by Paul J. Fox of the Chemical Laboratory, Bureau of Science.

[5] Analyses of Mancayan rock are by Mr. L. A. Salinger, Chemical Laboratory, Bureau of Science, Manila, P. I., 1905.

A comparison will show that although the silica remains fairly constant in amount, there is very little stability in the percentages of the other constituents excepting in the soda. This fact is not extraordinary and, indeed, it might be expected from variations in the magma in a distance of 50 miles, and from the subsequent alterations to which the rock has been subjected.

The exposure of the diorite in the Antamok River is continuous from Pakdal to a point a mile below Antamok, where a granitic intrusion (to be described later) comes in. The valley of Gold Creek is also in this rock, from its junction with the Batuaan to the headwaters at Pakdal.

On the north side of the area diorite again crops out where the drainage north and west of Baguio has cut deeper into the surface, and in various places in the Bued River cañon, where later sedimentaries and extrusives have been cut through, good exposures of the diorite are laid bare.

From below Camp IV, or Kias, on the Benguet road, the diorite does not outcrop, later extrusives and sedimentaries taking its place in the river bed, and it is evident from the occurrence of a massive intrusion of more granitic character to the east of this, that from this point on, the dioritic exposure leads off to the east toward the *Cordillera Central,* or in other words that on the topography of this basal mass, this southernmost point represents the limit of exposure of any great elevation. From here to the south, the diorite is evidently considerably lower and as may reasonably be supposed, is buried in the plains region between Benguet and Manila by a great thickness of recent sedimentaries.

INTRUSIVES.

About a mile to the south of Antamok, on the river of the same name occurs a massive exposure of a rock which here is classed as an intrusive, but which may possibly be but a phase of the diorite. On the Antamok and Batuaan Rivers, both of which cut across the contact between the diorite and the intrusive, the contacts are obscured by heavy talus and wash, and the relative ages of the formations, if they differ, can not be determined. The float on the Antamok River seems to show all variations in appearance from the one rock to the other. The rock may be classed in the field as a granite or quartz diorite. It is a hard, light-green massive rock showing to the eye quartz, feldspars, and a dark-green hornblende (?) arranged in a granular holocrystalline structure with particles of a light-green secondary mineral scattered throughout the feldspars. Under the microscope the minerals exhibited are quartz, plagioclase, amphibole and magnetite. The quartz does not form a conspicuous constituent and it occurs as an interstitial filling. The extinction angles measured on the plagioclase show it to be oligoclase in idiomorphic crystals showing zonal growth and considerable polysynthetic twinning. The amphibole is normal hornblende and the magnetite seems to occur principally as inclusions in the former, or adjacent to it. In the Bued River cañon, where the same rock occurs, a marked peculiarity is developed, which appears to be the presence of inclusions of diorite caught up in the quartzose magma. This "Kugelstruktur" (Rosenbusch) when examined under the microscope, is seen to be due to difference in texture, in fineness of grain, rather than in any difference of mineralogical composition, and as before, the sections show plagioclase, hornblende, magnetite and quartz, with a slight development of accessory sphene and secondary iron oxide. No explanation of this, other than variation in the magma, can be offered. The area covered by this phase of the quartz diorite is considerable, to judge from the length of the exposure in the Bued River cañon, and over all the area examined, these "inclusions" prevail. Although mapped as a separate mass, the weight of evidence tends to the view that the diorite assumes a more quartzose variation only locally, and that the Batwaan Creek area is a part of the diorite core.

Many small dikes of basalt cut through this rock, but they are unimportant, excepting that the directions of the dikes seem to be quite uniformly along east and west lines. In common with the system of ore deposits in the diorite, the majority of the veins striking east and west, or approximately in that direction, this prevailing direction would point to a line, or rather a direction, of weakness in the main mass of the rock. Three analyses[6] of these rocks are as follows:

Analyses of the basalt.

Constituent.	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Moisture at 110° (M—110°)	0.14	0.08	0.13
Loss on ignition (M+110°)	1.61	1.08	0.77
Silica (SiO_2)	57.49	58.35	57.06
Alumina (Al_2O_3)	18.40	16.70	20.00
Ferric oxide (Fe_2O_3)	5.46	4.08	3.03
Ferrous oxide (FeO)	1.71	3.28	3.01
Calcium oxide (CaO)	7.61	7.71	7.18
Magnesium oxide (MgO)	3.05	3.29	3.27
Potassium oxide (K_2O)	1.99	2.87	3.06
Sodium oxide (Na_2O)	3.38	2.62	2.95
Total	100.84	100.06	100.46

Numbers I and II are from Antamok River, Number III, from Batuaan Creek exposures.

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[6] Analyses by Paul J. Fox, Bureau of Science, Manila.

EXTRUSIVES.

The occurrence of comparatively recent eruptive rocks over a large part of the Baguio district is particularly noteworthy. North of the areas of quartz diorite, all the elevations are capped with extrusives of various types, but all show relations which point to one petrographic province for the series. Andesites and allied rocks prevail.

An exposure of limited extent within the area studied on the ridge east of the Antamok and east of the river is of a light gray-green volcanic rock which can not be classified in the field, more closely than as an augite-leucocphyre, although even this porphyritic development is rare and the rock generally is almost a felsite. Under the microscope, sections exhibit an orthophyric structure, the rock being composed of plagioclase (almost invariably fragmental) augite, and magnetite.

Determination of the feldspar is difficult, but measurements on one Carlsbad twin gave angles of extinction corresponding to oligoclase and while much shattered, the crystals are truly idiomorphic. Pyroxene is present in small amount throughout the slides, with sufficient indication of idiomorphism to justify the use of the term, and from the structure it is evident that crystallization of the augite has taken place later than that of the feldspars. The rock is much decomposed, breaking down into epidote and magnetite; chlorites are present in small amount, closely associated with the feldspars and augites. All sections show clearly that the rock is an extrusive (andesite), but that during crystallization or subsequently, great strain has developed, so that the rock is almost fragmental.

Two analyses[7] of this rock are given:

Analyses of the andesite.

Constituent.	I.	II.
	Per cent.	*Per cent.*
Moisture at 110° (M—110°)	0.44	0.52
Loss on ignition (M+110°)	2.23	2.04
Silica (SiO_2)	53.92	54.10
Alumina (Al_2O_3)	18.68	19.01
Ferric oxide (Fe_2O_3)	4.27	4.32
Ferrous oxide (FeO)	2.65	2.45
Calcium oxide (CaO)	8.85	8.90
Magnesium oxide (MgO)	2.93	3.02
Potassium oxide (K_2O)	2.66	2.98
Sodium oxide (Na_2O)	2.92	3.08
Total	99.55	100.42

[7] Made by Paul J. Fox, Chemical Laboratory, Bureau of Science, Manila, 1906.

Many outcrops of andesitic rocks are exposed on the Baguio-Kias Ridge, all more or less closely related in that they evidently represent one period of volcanic activity. These rocks vary from typical augite-andesites and andesite-porphyries to hornblende-porphyry, and certain other exposures can only strictly be classified as dacites. The rocks are so closely related that they are mapped as "andesitic rocks" to show their occurrence as subsequent and younger formations.

The rock in general is porphyritic in structure, the light-colored feldspar-phenocrysts showing prominently against the darker groundmass. Occasional exposures were seen which show a more granitic texture, but these are comparatively rare. Sections from one of the typical exposures on the Copper King Creek at the mill of the mine of the same name, show a rather abnormal cryptocrystalline groundmass with abundant phenocrysts of zonally constructed plagioclase, of hornblende and of magnetite. Investigation of extinction angles of the feldspar shows it to be labradorite, with occasional twinning according to the pericline law. Actinolite is the representative of the amphiboles, it rarely is unaltered, and then it shows pleochroism.

Saussuritization has taken place to a considerable extent and in many instances only outlines of the original feldspar are left. Magnetite is abundant in minute grains and is closely associated with the actinolite.

Specimens showing a pronounced porphyritic structure were collected from a dike in the Bued River a half mile above Kias, the plagioclase phenocrysts measuring as much as 0.5 inch in length, set in a dark groundmass. Under the microscope the feldspars show the characteristic alteration of the albite twins, and much calcite and epidote is seen. Oligoclase and andesine are identified in the fresher crystals. There is a second series of phenocrysts of a smaller size developed in the groundmass, and these, although badly corroded, are undoubtedly remnants of muscovite. Magnetite is present to a considerable extent, and both hematite and limonite scattered through the groundmass and the muscovite phenocrysts are in almost all sections.

A large exposure of a fine-grained andesite which is apparently a transitional rock, is found at a greater distance up the Bued River from this dyke variety of the andesitic eruptives. Its groundmass is light in color and the amphiboles make up the majority of the phenocrysts which are visible to the eye. This variety represents one extreme of the andesitic series of the district, and that next described, an augite-andesite from the Baguio Plateau, cropping out just south of the civic center of Baguio, the other. Megascopically it is a heavy, dark rock, breaking with a conchoidal fracture with a metallic ring. Small phenocrysts are seen in the groundmass, which can not be identified. It weathers on the surface to a brown clayey soil and decomposition has taken place

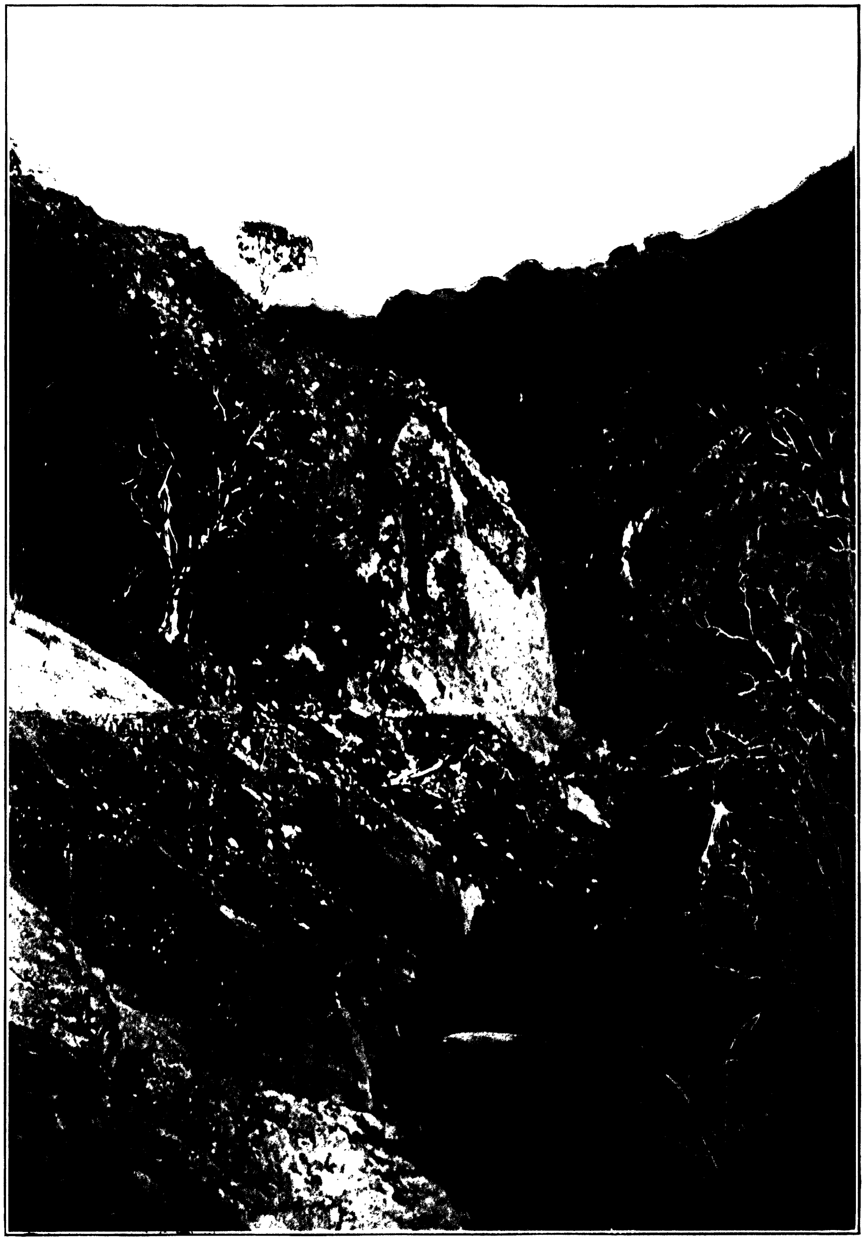

PLATE IX. BUED RIVER BEDS.

along a series of three directions of cleavage leaving hard and compact rounded boulders in the subsoil.

Under the microscope, augite is the most prominent constituent, with twinning parallel to the macropinacoids. The feldspars are plagioclase; oligoclase, andesine, labradorite and anorthite all occuring in at least two generations, if not more. The groundmass is typically andesitic in structure. Magnetite, in fine grains, is prominent in the groundmass.

All of the younger rocks described above are of andesitic varieties and in fact, with the exception of the two closely related rocks, the basal diorite and quartz diorite no other igenous rocks have been seen in this area, excepting andesite and related extrusives. There is a close petrographic and geologic resemblance between this district and the region around Mount Shasta (California), which has been described by Diller in Monograph 15 of the United States Geological Survey, and in general, between it and many of the petrographic provinces represented by the Pacific coast cones of Mount Hood, Mount Rainier and others. Spurr [8] has also recently called attention to this "Pacific Zone" of andesitic rocks.

SEDIMENTARIES.

Exposures of sedimentary rocks, although more prominent in the immediately adjacent areas, occur in the Baguio district, and from these a series can be constructed giving some fairly accurate idea of the geologic history of this region. At the base of this series, resting on the diorite rocks beneath, is a conglomerate of considerable thickness, made up of the dioritic materials derived from the basal mass. None of the exposures show a sufficiently large section to allow the taking of accurate measurements, but the conglomerate certainly must be considerably over 100 feet in thickness. The beds consist of heavy conglomerate at the bottom, with sandstones and clay above. No fossils have been found in these beds, but the one-foot lignite seam in the upper measures and the conformability of the beds with the Baguio limestone directly above them establishes the fact at least, that they are only a little earlier and older than the fossiliferous limestone. The material has little uniformity of size, and the bowlders vary from pebbles to rounded masses of many tons' weight. No outcrops of the conglomerate base are visible in the area, only the upper measures being laid bare in the upper end of the Bued River gorge. However, below, in the same cañon, for a distance of a few miles, the whole series is admirably exposed. The formation dips to the south on the southern end of the highlands and a few miles to the northwest of Baguio, to the west, the beds curve around the dioritic islet like a cape. The upper beds in the vicinity of Baguio are fairly rich in fossil remains, but they are in a bad condition for examination, and the best that can be said is to confirm the statement of Abella,[9] that present-day marine forms occur.[10]

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[8] Spurr, J. E.: Geology of the Tonopah Mining District, Nevada, *U. S. G. S.*, (1905), 47.

Resting on the conglomerate base is a heavy limestone bed, in places metamorphosed to marble (Bued River below "Colgan's Camp") by later andesitic extrusives. Almost everywhere it is rich in fossil remains. It is a yellow-white limestone, hard and compact, and excepting at the outcrops on the greatest elevation, fairly resistant to erosion. The limestone on the hills to the west of Baguio is in places heavily stained with iron oxide, giving it a deep rose color. At the bottom of the Bued River gorge, at the "zigzag" on the Benguet road, iron oxide in excessive amount has given the limestone a basaltic appearance, due to its black color and extreme hardness. When the rock is seen in thin sections, calcite, in large and small grains, with occasional evidence of recrystallization, is shown practically to form its entire mass.

The sections show specimens of:

Operculina complanata Bast.
Lithothamnium ramossissimum Ruess.
Textularia megeriana (?).
Polystomella sp.
Orbitoides sp.

At least one fossil which may provisionally be pronounced a nummulite has been observed, the "alar prolongations" being well developed. Mr. W. D. Smith, who furnished the above data, has examined other limestones, in a region farther to the south in Luzon, in Cebu and in Batan Island, and all the paleontological evidence indicates the presence at one time of continuous beds of limestone, which can with fair safety be classed as Miocene, extending throughout the Philippine Islands, or at least throughout such parts of the Archipelago as were under the proper topographical conditions at the time it was deposited. A further study of broader areas than this small Baguio district is expected to add much to the stratigraphic correlation of these beds. An analysis[11] of the white limestone from the vicinity of Baguio is as follows:

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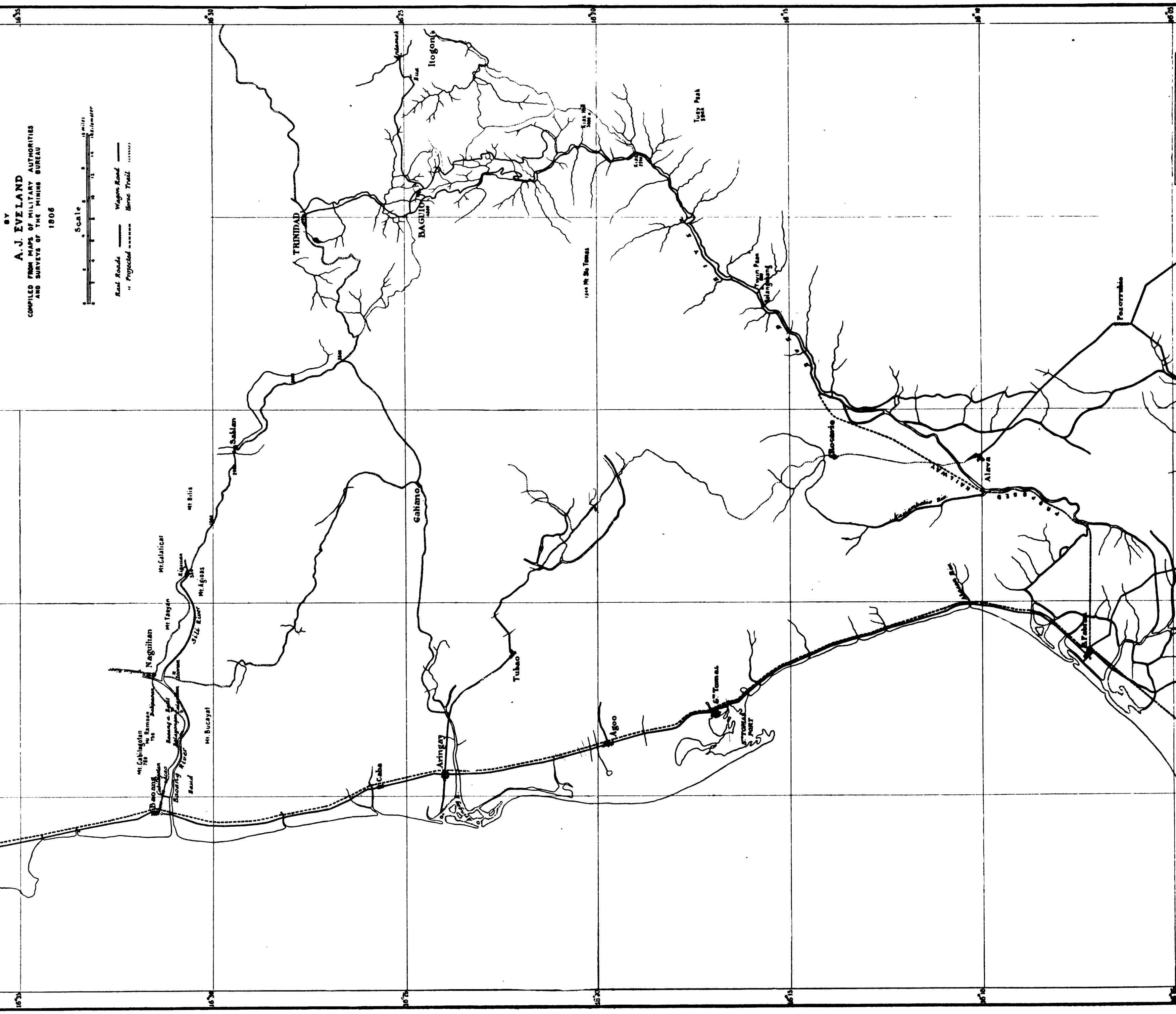
[9] Abella: Terremotos de 1892 (1893), 33.

[10] Since this paper was written these fossils have been examined more carefully and with the aid of literature which we have since obtained we are able to single out several forms, the same as, or closely related to, Javan and Bornean forms which are certainly Tertiary and one, *Turbo borneënsis,* which seems to be confined to the Eocene. These fossils are all casts and poorly preserved, making exceedingly unsatisfactory material to work with.—W. D. SMITH.

[11] Made by L. A. Salinger, Chemical Laboratory, Bureau of Science, 1906.


BY
A. J. EVELAND
COMPILED FROM MAPS OF MILITARY AUTHORITIES
AND SURVEYS OF THE MINING BUREAU
1906
Scale
miles
kilometer
Rail Roads
" Projected
Wagon Road
Horse Trail
16°35
16°30
16°25
16°20
16°15
16°10
16°05
TRINIDAD
BAGUIO
Itogon
Tuzy Peak
Mt. Sto. Tomas
Sablan
Mt. Bilis
Mt. Calalical
Mt. Agoos
Mt. Tauyan
Naguilian
Mt. Ramon
Mt. Cabilangtan
Mt. Bucayat
Bauang River
Bauang
Caba
Galiano
Aringay
Tubao
Agoo
Sto. Tomas
Sto. Tomas Port
Rosario
Alava
Pozorrubio
Manila Railway
Bued River
Dagupan

Analysis of the limestone.

Constituent.	Per cent.
Moisture (—110°)	0.16
Loss on ignition (+110°)	42.49
Silica (SiO_2)	1.90
Alumina (Al_2O_3)	1.72
Ferric oxide (Fe_2O_3)	.30
Ferrous oxide (FeO)	.04
Calcium oxide (CaO)	52.11
Magnesium oxide (MgO)	.97
Potasium oxide (K_2O)	.07
Sodium oxide (Na_2O)	.20
	99.96

TUFFS.

Exposures of what are undoubtedly pyroclastic rocks, now indurated to a solid rock mass, occur in the immediate vicinity of Baguio on the rounded hills near the town. The best exposures of these are on the Baguio-Trinidad road, near Baguio. The rock is a purple-brown hard and compact heterogeneous mass, to certain phases of which the name "eruptive conglomerate" has been given in the field. The name expresses the rock texture, which varies from a medium-grained variety to one which is extraordinarily coarse. The material is entirely andesitic, and two varieties of andesite are present, differing only in their groundmasses, as evidenced chiefly by the color of the latter. In thin sections, the loose texture of the rock is striking, being merely an aggregate of minerals, all of the grains being more or less rounded. The minerals present are the light-colored, monoclinic pyroxenes, hornblende, actinolite, plagioclase, magnetite and in areas, olivine, the tuff being in these localities more basaltic than andesitic. The pyroxene is the most prominent mineral, making up fully one-half the slides. It is greenish-yellow to almost colorless in various sections, and not pleochroic. It is fragmentary, very irregular, generally rounded and shows prismatic cleavage.

The feldspar is almost insignificant in amount, generally occurring in small grains. Magnetite is present in large amount, being second only to the pyroxene in abundance. The epidote which occasionally occurs is idiomorphic and can readily be distinguished from either hornblende or pyroxene by the marked basal parting. A microspherulitic structure of feldspar, quartz (?), and magnetite is noteworthy, as is also the intergrowth of feldspar and hornblende.

This rock in addition to the Baguio outcrops, is very prominently exposed on the road through the Pias Valley and on the Copper King road near Loacan. Other exposures on the east side of the Antamok

River show that the formation has existed, at one time, over a greater area from which it has been eroded. It is probable that field work beyond the district will also show this striking rock.

ORE DEPOSITS.

Although the present paper was planned as a contribution to economic geology, the study of the area has shown that the present stage of development of the ore deposits which have so far been found, does not warrant an extended investigation of them at present, nor would it, under such circumstances, be of more than descriptive value. It is therefore unnecessary more than briefly to touch on the occurrence of valuable ores within this district.

The native (Igorot) has for a long time, in a semi-skilled manner, worked such gold-bearing rock as has come to his attention, and the presence of the old working naturally led to their exploitation by the American miners, most of whom came in the army of occupation within the last decade. The Baguio district up to the present time has been prospected or developed in three, more or less distinct, districts, the Kias region, the Copper King or Bued River region, and the Antamok region. In all of these districts, deposits occur, associated with the igneous basal diorite or the closely connected volcanics.

SUMMARY OF THE GEOLOGY.

The geology of this region shows that we have a basal mass of dioritic rocks as the oldest rock which is laid bare, and this may be accepted as the beginning of the geological history of Luzon, until further data are collected from wider areas. During the gradual and prolonged submergence of this base, which is probably an eroded stump in the form of an islet, the basal conglomerate of the Bued River was laid down and on it the rest of the series of sandstone and clays, in which so far no fossils have been found. The limestone of the Bued River was built upon these in perfect conformity, and all paleontologic and stratigraphic evidence so far goes to show that this building occurred during the Miocene, after uplift and folding, erosion and base leveling commenced. Following this, or possibly at the beginning of the Miocene, that neovolcanic period began which also produced the "eruptive conglomerate" and tuffs at a later time. During this period the ore deposits which may have existed in the basal rocks may have been modified, and later deposits formed.

To judge from the physiographic evidence, there have been minor changes in level, in addition to normal base-leveling, which have produced the topographic features of the district.

Oversized
Foldout

ILLUSTRATIONS.

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PETROGRAPHY OF SOME ROCKS FROM BENGUET PROVINCE, LUZON, P. I.[1]

By WARREN D. SMITH.
(*From the Division of Mines, Bureau of Science.*)

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  Andesite tuff.
  Andesite porphyry.
  Graywacke.
  Foraminiferal limestone.
ILLUSTRATIONS.

INTRODUCTION.

Mr. Eveland in his paper "Notes on the Geology of the Baguio Mineral District"[2] has described the field relations of the rocks, the more detailed petrography of which I have taken for the subject of this paper.

In the following pages I propose to give a description of each rock, which I wish could have been much more minute and exhaustive but time did not permit of more extensive work. I have included diagrams and photomicrographs and in addition have added some tables, using the quantitative classification.[3] Many of our Philippine rocks are classified with difficulty according to this system, owing to their greatly decomposed and altered condition, and it is only applicable to comparatively fresh rocks, which we rarely obtain except in mines and road cuttings, and of these unfortunately we as yet have few.

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[1] Supplementary to the paper by A. J. Eveland on the "Geology and Geography of the Baguio Mineral District." *This Journal*, Sec. "A," Gen. Sci. (1907), 4, 207.

[2] Eveland, A. J.: Notes on the Geography and Geology of the Baguio Mineral District. *This Journal*, Sec. "A," Gen. Sci. (1907), 4, 207.

[3] Quantitative Classification of Igneous Rocks; Chicago (1903).

More than one geologist[4] who has made studies along the great Pacific arc has remarked upon the striking similarity existing in the geology along all its points in California, Alaska, Japan and the Philippines.

A member of the United States Geological Survey, one who has had abundant opportunity to study the geology both of western America and portions of Asia, writes to me as follows:

> Although the Pacific lies between and seems to separate you from the more familiar phases of the geology of North America, I am of the opinion that geologically you are more in touch with our western coast than the man who is studying the geology of the eastern United States. The ocean basins are the sources of the great dynamic effects which characterize the continental margins, and there is more likeness between the opposing shores of the Pacific than there is between the opposite sides of the continents. I have been interested in the course of my work to find that the geology of California is the geology of central China, and that there is a close likeness even in the character and date of mineral deposits between our Western Cordillera and the East Indies. These similarities in geologic history, in orogeny, in vulcanism, and even in mineralization are too close and too long continued to be fortuitous. We shall reach an understanding best by regarding the ocean as the center and the continental region as the periphery, and by recognizing that the major phenomena differ when we cross the periphery from the sphere of activity of one ocean to that of another.

I must say, after attempting to make use of the quantitative classification, that it is not well adapted to our Philippine rocks. I believe that in their almost universal condition of decomposition here, classifying them after this manner would only be misleading. It does not seem justifiable, at least in many cases, to employ a system which neglects the actual mineral composition and uses an altogether arbitrary standard or norm.

The papers by Mr. Eveland and myself, then, only serve as an introduction to this region. There are many questions which we have thought over and upon which we have gathered some notes, but the time is not ripe for the close study which they demand for their solution. Some of these are:

1. Relation of the period of vulcanism to the deposition of the ores.
2. Relation of the vulcanism to the physiography.
3. Relation of amount of ejecta to elevation and subsidence.
4. The probability of past glaciation in the highlands of north central Luzon.

In this connection I may state that there are many features, such as boulders and boulder-clay, strongly resembling moraines; ponded drainage; peculiarly rounded and veneered hills; valley trains, etc., which have not received full treatment in the foregoing paper of this number for several reasons, the chief among these being the incompleteness of the evidence. Markings suggestive of glacial striæ have been reported to me by men who are in their own fields considered good observers. It is needless to say that before such a startling announcement as glaciation in this region can be made much more work in the area should be carried on, and this is proposed for the early part of 1908. The bearing of the possible discovery of glaciation upon problems of tropical animal and plant distribution, would of course be profound.

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[4] Becker, G. F.: Geology of the Philippine Islands—Extract. *21st. An. Rept. U. S. G. S.* (1902), 518.

I have made use of the new method of Dr. Eugene Wright in the determination of feldspars and have found it highly satisfactory. It will be recalled that this method makes use of a series of standardized oils composed of definite proportions of cedar, cinnamon and clove oil.

I wish here to acknowledge some assistance rendered by my colleague, Mr. H. G. Ferguson, in the preparation of the tables in this paper.

Bibliography of Benguet petrography.

1878—*Drasche, R. Von.* Fragmente zu einer Geologie der Insel Luzón (Philippinen), mit einem Anhange über die Foraminifera der Tertiären Thone von Luzón, von Felix Karrer. Vienna, Gerold's Sohn.

1881—*Oebbeke, K.* Beiträge zur Petrographie der Philippinen und der Palau-Inseln in *Neues Jahrbuch f. Mineralogie*, etc. Beilage, Band 1, Stuttgart, Koch.

1893—Abella y Casariego, Enrique. Terremotos experimentados en la isla de Luzón durante los meses de etc. Manila Chofré 8°, 110 pp. 1 diagram and map.

1893—Abella and others. Estudio descriptivo de algunos manantiales minerales de Filipinas etc. Manila, Chofré, 8°, pp. 150.

List of Benguet rocks described in this paper.

Series No.	Field No.	Name.	Locality.	Page.
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BENGUET NO. 4.—QUARTZ DIORITE.

The primary minerals present are plagioclase, amphibole, quartz, magnetite.

Feldspars.—The plagioclases correspond to oligoclase, as all the extinction angles are almost without an exception low, 8° or very close to that figure; the index of refraction is also lower than that of quartz, showing that these feldspars could not be either labradorite or anorthite. They occur in idiomorphic crystals showing zonal growth in many cases and much polysynthetic twinning according to the albite law. No good Carlsbad twins could be made out, but this form of twinning does occur. The average diameter of the feldspar sections varies from 0.5 to 1.5, and 2 millimeters is the extreme observed.

Quartz.—Occurs as an interstitial filling. It does not form a conspicuous constituent of any of the sections from this rock.

Amphibole.—Some ragged sections parallel to prism and fragments of basal sections form a small portion of the section. The amphibole is grass green, extinction angle about 17°.

BENGUET NO. 12.—QUARTZ DIORITE.

This is a section of a typical quartz diorite. It is quite fresh, showing little or no alteration. The texture is granitic, the holocrystalline, fabric *hypidiomorphic-granular.* The minerals of the rock are plagioclase and orthoclase feldspar, hornblende (actinolite) quartz, magnetite, and accessory apatite. The feldspars for the most part are plagiocalse, exhibiting both Carlsbad and albite twinning. From the extinction angles which were taken on a section cut normal to the albite twinning I made out this piece at least to belong somewhere near the middle of the series, oligoclase or labradorite. Some orthoclase is present, associated more or less with the quartz. It is decidedly not the dominant feldspar. The amphibole is the pleochroic, grass-green variety known as actinolite with pleochroism as follows: $\mathfrak{b}$=colorless to yellow; $\acute{c}$=dark green. Quartz occurs wholly as interstitial material. Magnetite is found as minute, rounded grains inclosed by hornblende.

A series of measurements on this slide establish the following approximate proportions of the various minerals, from which was calculated the following analysis.

Constituent.	Per cent.
Quartz	2.94
Plagioclase	67.09
Hornblende	22.93
Magnetite	6.28
Olivine	.73

Magnetite is largely confined to the region of the amphiboles, either as inclusions or in juxtaposition.

Accessory minerals an almost entirely lacking or so inconspicuous as to warrant no lengthy search for them.

The rock is a *quartz diorite*.

Constituent.	Calculated from mineral contents.	Calculated by chemical analysis.
	Per cent.	Per cent.
SiO_2	56.89	57.06
FeO Fe_2O_3	8.58	6.04
Al_2O_3	17.52	20.00
MgO	2.9	3.27
Na_2O	7.32	2.95
CaO	3.97	7.18
H_2O	....	3.06
	97.18	100.00

Plate II, fig. 1, is a photomicrograph, taken with polarized light, of this rock.

Remarks.—A greater number of measurements would doubtless raise the silica content by showing more quartz. In this calculation the orthoclase was taken with the plagioclase. This, in close work, strictly should not be done. Making allowance for orthoclase we should have a lower Na_2O figure and about 3 per cent of K_2O.

Examination of additional sections of this rock revealed some small amount of biotite.

TABLE I.—*Benguet No. 12.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Anorth.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	57.06	951	198	288	230		24	91	116
Al_2O_3	20.00	196	33	48	115				
Fe_2O_3	6.04	19				19			
FeO		42				19	3	29	
MgO	3.27	82					11	71	
CaO	7.18	129			115		14		
Na_2O	2.95	48		48					
K_2O	3.06	33	33						
	99.56								

Constituent.		Norm.				
Quartz		0.116	6.96	Q 6.96		Salic 82.43
Orthoclase		.033	18.35			
Albite		.048	25.15	F 75.47		
Anorthite		.115	31.97			
Diop	Ca	.014	1.63			
	Mg	.011	1.10	3.13		
	Fe	.003	.40		P 12.87	
Hyp	Mg	.071	7.10	9.74		Ferric 17.28
	Fe	.020	2.64			
Magnetite		.019	4.41		M 4.41	
			99.71			

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 3. Andase.
Subrang 3. Shoshonose.

BENGUET NO. 13.—DIORITE.

This slide is from a *diorite* also, but one which is not so fresh. It contains triclinic feldspars, most probably labradorite, as the following figures were obtained from Carlsbad twins, 20° to 26° and 11° to 12°. One very noticeable feature of this slide is the great number of small, rounded grains of quartz and feldspar in the interstices of the plagioclases. The slides give the appearance of the rock having suffered a granulation and recrystallization in some portions. This hypothesis is apparently supported by the appearance of some of the feldspars. One in particular is something like Plate I, fig. 2. The characteristic alteration in zones in the plagioclase is shown in Plate I, fig. 2. In one of the Carlsbad twins a structure very similar to what is known as microperthitic is to be seen.

The amphibole is of the green, pleochoroic variety, actinolite, but much altered.

The above figures on the Carlsbad twins are supported by investigation of other slides from the same rock where sections normal to the albite twinning gave 31° to 33° maximum extinction, proving pretty conclusively that the feldspar is *labradorite*. The structure of this rock may be termed hypidiomorphic granular to cataclastic.

BENGUET NO. 16.—DIORITE.

This slide is largely made up of plagioclase feldspars which show much polysynthetic twinning. No twinning other than the Albite was noted. The other minerals are magnetite, chlorite and calcite, these latter being very intimately associated, as they are all undoubtedly products of the alteration of the feldspars.

As far as the feldspars are concerned, the structure is described by Rosenbusch's term pan-idiomorphic, and pan-idiomorphic-granular with reference to the whole rock. The feldspars were apparently the first to crystallize from the magma. In some sections the structure is almost that of a porphyry.

No good sections suitable for measuring extinction angles of the plagioclase were found, although from the presence of the calcite one would infer that they belonged to the lime end of the series. Some of these feldspars show a structure closely resembling what is termed microperthitic, and which is usually produced by an intergrowth of two or more kinds of feldspar.

The chlorite is the light green mineral with low index of refraction, it is scattered in flakes and stringers all through the slide. However, it has not been seen anywhere in the slide to possess a radial structure, usually so prominent in the case of this mineral.

In several patches in the slide the three minerals, magnetite, chlorite and calcite are grouped indiscriminately together as if resulting from the alteration of some former ferromagnesian mineral, rich in calcium, such as diopside or actinolite. One or two very large patches of calcite make it appear quite probable that some calcium has been introduced from the outside.

Magnetite constitutes fully 10 per cent of some of the slides of this rock. There is also a small amount of pyrites.

TABLE II.—*Benguet No. 16.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Acmite.	Mag.	Diop.	Hyp.	Oliv.
SiO_2	49.89	832	6	108	56		384	260	18
Al_2O_3	1.87	019	1	18					
Fe_2O_3	2.61	016			14	2			
FeO	23.47	326				2	128	193	27
MgO	6.57	164					64	87	13
CaO	10.75	192					192		
Na_2O	2.01	032		18	14				
K_2O	.09	001	1						
H_2O	3.53								

Constituent.		Norm.				
Orthoclase		.001	0.56	F 9.99	Sal 9.99	
Albite		.018	9.43			
Acmite		.014	6.47	6.47		
Diopside	Ca	.192	22.27			
	Mg	.067	6.40	45.57	P 83.58	
	Fe	.128	16.90			
Hyp	Mg	.087	8.70	31.54		
	Fe	.173	22.84			Fem 88.44
Oliv	Mg	.006	.84	4.40	4.40	
	Fe	.021	3.56			
Magnetite		.002	.46		M .46	

Class	V.	Perfemane.
Subclass	I.	Perfemone.
Order	1.	Maorare.
Section	I.	Caroliniare.
Rang	1.	Websterase.
Subrang	4.	(Doferrous.)

BENGUET NO. 150.—GRAYWACKE.

Macroscopic.—Is an aphanitic, medium-grained, hyp-automorphic granular rock of a speckled white and green color. This rock is not very unlike a coarse-grained sandstone. Feldspar is practically the only mineral distinguishable with the naked eye.

Microscopic.—This is unmistakably a fragmental rock, but it is not so easy to say positively whether it is a normal sedimentary derived from land wear or of pyroclastic origin. Under the microscope one sees a confused mass of minerals, some rounded and some angular, consisting of quartz, orthoclase, plagioclase, magnetite, chlorite, and numerous saussuritization products such as quartz, epidote and possibly calcite. Under a high power the closely knit appearance of the mass almost leads to the belief that this is a true igneous rock, but with lower power, when a proper view of the whole can be obtained, its true texture is plain and it is evident that the pseudo-igneous texture is due to the matrix of chlorite and iron compounds which cement the larger grains.

Remarks.—I would call this rock a graywacke for the following reasons:

1. Its composition.
2. Its fabric, the rock consisting of an aggregate of more or less independent, rounded and angular minerals, not rock fragments as in the true tuffs (see numbers 101 and 103).

BENGUET NO. 153.—QUARTZ DIORITE.

Macroscopic.—This is a phanero-crystalline, medium-grained (with finer grained inclusions) xenomorphic rock of a pepper and salt color. The rock consists largely of more or less irregular and ill-defined feldspar and ferromagnesian minerals, the darker minerals possessing more nearly idiomorphism. In the white, dull feldspar patches there are minute pinkish areas of orthoclase. The predominent feature about this rock is the magmatic differentiation. The cryptocrystalline areas, usually 1 to 2 cubic centimeters across, are in every case darker than the remainder of the rock and the border between the two areas is generally sharp.

Microscopic.—In the hand specimen this is not greatly unlike the Kobe (Japan) granite. For the most part it is coarse grained and possesses the typical granitic texture. In both rocks the characteristic feature is the areas of darker, more fine-grained portions, which almost have the appearance of foreign material caught up in the crystallizing magma. This is the "Kugel Structur" of Rosenbusch and described by him from the Corsican "Kugeldioriten von S. Lucia di Tallano bei Sartene." (See p. 120, Rosenbusch, Massige Gesteine.)

Two very distinct areas are seen under the microscope, which, however, differ more in texture and abundance of certain minerals than in the mineral composition itself. The same minerals appear in both areas, but in different proportions. The minerals found are:

Primary.	Plagioclase. Hornblende.	Accessory: Sphene.
	Magnetite. Quartz.	Secondary: Iron oxide.

This makes the rock a *quartz diorite*. The quartz is not secondary, as is shown by its relations to the other minerals, at least it is not the case with all of it.

Plagioclase.—This is the most abundant constituent of the slide, found in large, idiomorphic sections, showing both albite and Carlsbad twinning. Extinction angles on section showing albite twinning gave the figures 20° to 22° which would throw these plagioclases in with andesine.

Hornblende.—For the most part in broken prism sections, pleochroic c = dark green, a = yellowish, in thinner section it would be nearly colorless, it forms the next most abundant constituent of the slide, most prominent in the "Kugel" areas, where it is as abundant or even more so, than the feldspars. However, it occurs in these areas in very small, irregular grains, much smaller than in the more coarse-grained portions. Where good contacts can be studied it appears that the hornblende crystalized first.

Quartz.—Probably makes up 2 to 3 per cent of the slide as interstitial material.

Magnetite.—Present, but not very abundant. Largely confined to the body of the hornblende.

Sphene.—Occasional, stray crystals of small size.

Iron oxide stains the slide here and there.

Plate II, fig. 2, is a photomicrograph, with polarized light, of this rock.

Remarks.—From all the indications that can be gleaned from the slide, the darker "Kugel" areas simply represent a differentiation in the original magma. This part, it is my idea, was a little richer in the constituents that make up the ferromagnesium minerals; certain conditions must have prevailed more favorable for the production of hornblende than pyroxene, these were conditions of pressure, temperature and the composition of the magma, the intimate relations of which are just beginning to be understood. The results seem to be more in the nature of a concretion and the law of mass action appears to have entered largely into the process.

An examination of the boundary between the darker, fine-grained areas and the rest of the rock does not reveal a sharp line, although on macroscopic examination it does appear so. Under high power the boundary is irregular and chrystals from both areas penetrate each portion. Quartz seems to be more abundant along the contact than anywhere else in the slide. Just at that point the rock solution may have been depleted of alumina, etc., through the formation of excessive amounts of hornblende in the "concretionary" part.

BENGUET NO. 116.—DACITE.

Macroscopic.—A hypocrystalline, rather aphanitic rock, which has a somewhat porphyritic fabric and is greenish-yellow. The rock has a dense, bluish, fine-grained ground mass in which are numerous phenocrysts of epidote, themselves not large, rounded areas which appear to be decomposed feldspars and occasional, clear, limpid, more or less rounded or irregular, areas of quartz. There are very few ferromagnesian minerals visible in the hand specimen, and they are mere black specks.

Microscopic.—The prominent features of the slide are:

1. The saussuritized feldspar (plagioclase) phenocrysts.
2. The comparatively clear, rounded phenocrysts of quartz.
3. The ground mass in places quite trachytic, in others glassy, the whole having a felty or hyalopilitic character.

The existence of the ferromagnesian minerals, pyroxenes, or amphiboles can only be inferred as alteration has left no recognizable remnants.

Remarks.—The alteration of the plagioclase has gone so far that scarcely a trace of the polysynthetic twinning can be made out; however, the outline of the original mineral is still preserved. The interior of these phenocrysts is usually taken up with quartz and epidote, some of which is the low, doubly-refracting zoisite.

Pyrite is abundant in some of the slides, magnetite in all of them.

BENGUET NO. 106.—HYPERSTHENE AUGITE ANDESITE.

Macroscopic.—An almost black aphanitic, for the most part microcryptocrystalline rock, but plainly porphyritic. The larger phenocrysts, not over 2 millimeters in diameter, are jet-black amphiboles or pyroxenes, while there are smaller, lath-shaped feldspars, which are apt to be overlooked unless the light strikes them. These are about 2.5 millimeters in length by 0.5 millimeter wide, and are striated. Occasional larger, glassy spots of what is probably quartz are also to be seen.

Microscopic.—This rock in thin section reveals a distinctly porphyritic structure, large, square and brick-shaped feldspars, plagioclases, and pyroxenes occur, also idiomorphic in a groundmass, which varies from vitreous to cryptocrystalline, and also holocrystalline.

There are a number of large, irregular, also sometimes square sections of magnetite in the slide, as well as innumerable fine grains of it in the groundmass.

The plagioclases show both albite twinning and zonal structure. Sections normal to the albite laminæ give extinction angles of 26° to 28°, thus corresponding to andesine. One zonally built crystal of feldspar appeared to have an outer coating of anorthite. Carlsbad twins also are not infrequent but the thickness of most of the slides of this rock prevent close investigation of their extinction angles. Plate I, fig. 3, shows typical appearance of altered feldspar or rather of one which is about three-fourths decomposed.

The pyroxene is largely hypersthene and exhibits marked pleochroism, but augite, which reveals none, is also to be seen in the slide. Plate I, fig. 4, shows the habit of the hypersthene in this rock.

Plate III, fig. 1, is a photomicrograph of this rock.

Remarks.—In one place augite has grown around the hypersthene, having crystallized later. It would also appear that the plagioclase had crystallized after the hyphersthene. From evidence in the slide it would seem as if the felspar and the augite cystallized out almost simultaneously. Plate I, fig. 5, shows a basal section of augite twinned parallel to the macropinacoid.

It appears, from the descrptions by Diller, Iddings and Becker, that we have here a hypersthene-augite andesite very nearly identical with the recent lavas of Shasta County, California, and the Comstock Lode, Nevada. See *Bull.* **150** *U. S. G. S.*, Diller; also Geology of the Comstock Lode, Becker; also *Mon.* **20,** *U. S. G. S.*, 364.)

BENGUET NO. 107.—AUGITE ANDESITE.

Microscopic.—This rock is almost an exact duplicate of No. 155. Phenocrysts of plagioclase and augite lie imbedded in a typical groundmass of small, lath-shaped feldspars arranged in an orthophyric manner, making a typical andesitic groundmass. Some of the slides are thick, so that this structure of the groundmass can not be seen, but one slide shows it well.

The feldspars show extinction angles varying from 10° to 31°, so that the phenocrysts vary from oligoclase to labradorite. All the phenocrysts are quite fresh. The augite occurs in idiomorphic sections, both basal and prismatic. One prismatic section (Plate I, fig. 6) shows twinning and cleavage. The twinning plane is not exactly parallel to $\dot{c}$.

Magnetite is very abundant, but in rather small grains in the groundmass. In one slide there are remnants of a substance indicating the former presence of hornblende, but we can not be sure that the slide contains any hornblende or amphibole.

BENGUET NO. 101.—ANDESITIC TUFF.

Macroscopic.—This is a heterogeneous mixture of particolored fragments, which are angular pieces of lava in various states of crystallization. The groundmass is uniformly fine grained and dark-red to brownish-black in color. The fragments which we find well cemented here were evidently blown out of some volcanic vent and afterward rendered compact under water. Occasional large crystals of hornblende, 5 by 7 millimeters, can be seen. The rock fragments are for the most part hornblende andesite. The largest fragment in the hand specimen is 22 by 12 millimeters.

Microscopic.—These are sections from what we may term an "eruptive conglomerate," or more properly speaking, an agglomerate of eruptives. All the material appears to be andesitic, there being two main kinds. These two differ chiefly in the material of the groundmass and this is evidenced mainly by the color, one portion, making up the larger part of the slides, being dark reddish or brownish.

Green hornblende, actinolite, and the light-colored monoclinic pyroxenes are present making up about one-half the slide.

The feldspars are plagioclase, but more than this we can not tell from the slide, as alteration and thickness obscure the albite twinning.

Epidote as an original constituent is seen in one slide. It is perfectly idiomorphic and appears in outline as shown in Plate I, fig. 7.

The marked basal parting distinguishes this from hornblende or pyroxene. There is scarcely any pleochroism.

Plate III, fig. 2, is a photomicrograph of this rock.

Remarks.—One of the noteworthy features of this rock is the intergrowth of feldspar and hornblende. (Plate I, fig. 9.) The feldspar is found in irregular grains all through the hornblende with a sharp, clean-cut line between the two minerals. Their appearance is decidedly *not* that of alteration of the hornblende, for they are in a very fresh state.

Magnetite, as usual, is quite abundant, though in small grains.

BENGUET NO. 102.—ANDESITE TUFF.

Macroscopic.—This apparently is a phase, though somewhat different, of Nos. 101 and 103. The rock fragments are larger and somewhat more rounded. The different portions of the rock vary considerably in color—that is, they are almost black, the color changing through chocolate to greenish-yellow—and the grain varies from exceedingly fine-grained portions to those containing phenocrysts of considerable size.

Microscopic.—This rock is evidently an intermediate phase between Nos. 101 and 103. The mineral composition is practically the same, plagioclase, pyroxene, hornblende(?), and magnetite. If there is any quartz present, it is in very minute quantities. However, there are two very noticeable features as exhibited in one slide. One of these, and perhaps the most important, is the pseudo-microspherulitic structure. Plate I, fig. 8, will show the relationships.

The second feature is the fairly abrupt contact between the darker and lighter portions of the rock. The darker differs merely in the possession of more iron staining its groundmass. Under the microscope this line appears far less regular than in the hand specimen, and the two portions of the rock dovetail along this boundary.

BENGUET NO. 132.—ANDESITE PORPHYRY.

Macroscopic.—A coarse-grained, porphyritic rock consisting of large, approximately square phenocrysts of white, dull to greasy looking feldspars set in a cryptocrystalline groundmass of a bluish black color. An average phenocryst measures 7 by 9 millimeters. Minute grains of a white mica are found as inclusions of the feldspar. The groundmass is slightly vesicular.

Microscopic.—On microscopic examination the groundmass, and the phenocrysts as well, are seen to be cryptocrystalline. Alteration has gone quite far and this is the reason for the oily appearance of the phenocrysts which are of two kinds and sizes, the larger were originally plagioclase. This is proved by occasional albite twinning in the unaltered remnants. They are nearly quadratic in outline.

The smaller phenocrysts occur with lath-shaped outlines, sometimes in rude, pseudo-hexagonal sections but more often they are rounded and badly corroded, being accompanied by a dark-greenish reaction rim, probably consisting in part of ferrous iron. They are undoubtedly remnants of muscovite.

Some small amounts of magnetite, more hematite and limonite can be seen scattered throughout the groundmass and the muscovite phenocrysts. The alteration products of the muscovite could not be made out even with the highest power (oc. No. 3, obj. No. 9); all that could be seen was a granular mass or very small, irregular, doubly refracting bodies.

Plate IV, fig. 1, is a photomicrograph of this rock.

Remarks.—The alteration of the feldspars is the characteristic saussuritization, with calcite and epidote certainly formed.

By testing a fragment of the less altered portion of the feldspar with a standardized oil, I found the unaltered portions to have an index Na 1.545 to Na 1.554, corresponding to that of oligoclase and andesine.

BENGUET NO. 126.—ANDESITE PORPHYRY.

Macroscopic.—This rock in the hand specimen has a yellowish-gray color, rather fine texture, yet apparently it is granitic. Occasionally a patch of finer grained and darker material is present, suggesting an orbicular structure.

Microscopic.—In thin section the most striking feature of the rock is the state of alteration of practically all the minerals. The feldspars are no longer clearly recognizable. They are very much altered, but retain their original outlines. Their arrangement in places is almost ophitic, in others trachytic. Rounded and irregular grains of what was originally hornblende and magnetite are all that remain of the original minerals.

Chlorite in large patches with radial structure is the most prominent secondary mineral.

Calcite in veinlets and also as an alteration product of the feldspars is quite plentiful. Large patches of radial chlorite with blebs of calcite scattered through them are quite characteristic of the slide.

Some secondary epidote is found closely associated with the feldspars.

Remarks.—At first glance one might be inclined to call this rock detrital, but an occasional feldspar with idiomorphic outlines and the structure of the rock would preclude this.

From examination of the hand specimen and the slides I should call the rock a dike rock—a phase of andesite porphyry.

BENGUET NO. 23.—FELDSPAR PORPHYRY.

This is a porphyritic rock in which zonally built plagioclase feldspars are the phenocrysts. There are also some large magnetite crystal sections, more or less idiomorphic, in the slide.

The groundmass is trachytic and made up of small, lath-shaped sections, and an abundance of minute magnetite particles.

Calcite is fairly abundant, being associated with feldspars; in some cases large patches of calcite can be seen inclosing a few small grains of feldspar; then again the calcite occurs as irregular stringers through the feldspar. Clearly it is a decomposition product of the feldspar. Chlorite is also in evidence in irregular patches between the larger minerals. It is almost impossible to specify the particular composition of the plagioclases, as no good prism faces nor sections cut normal to the albite twins were found. However, one zonally built plagioclase was investigated with the result that the center was found to have about the composition of oligoclase, with albite forming the outer shell. The only name I feel warranted in assigning to this rock is that of *feldspar porphyry.* The rock is far from being fresh. Plate IV, fig. 2, is a photomicrograph, with ordinary light, of this rock.

BENGUET NO. 103.—BASALTIC TUFF.

Macroscopic.—This rock is apparently made up of the same materials as No. 101, although it is in a much finer state. The groundmass is possibly somewhat more prominent and hence the rock is more nearly of its color, which is a chocolate-red. The largest fragments in this specimen do not exceed 3 millimeters in length. These is no effervescence with acids.

Microscopic.—When we study the slides of this rock the supposition that this is simply a finer state of No. 101 seems to be borne out, for few rock aggregates are seen as in No. 101, merely a loose textured aggregate of minerals, quite fragmental in appearance is visible. The grains are all more or less rounded, although not all to the same degree as in sandstone or quartzite.

The most abundant mineral of the rock is pyroxene, greenish-yellow in some sections, almost colorless in others, yet it is not pleochroic. It occurs as mere fragments, irregular and rounded, usually showing prismatic cleavage. Olivine also in rounded grains, colorless and possessing irregular cleavage cracks, can be seen in several places in the slide.

Magnetite is probably the most abundant mineral after pyroxene. It is sometimes seen inclosed in the pyroxenes. Feldspar is reduced to a minimum in these slides, usually occurring as very small grains and in one case only showing any distinct twin striations. In some of the slides fragments of actinolite were seen. These were generally pleochroic. The presence of both actinolite and augite is assured, as one portion of a basal section was found. These minerals are frequently seen to be surrounded by opaque masses of hematite and limonite.

Remarks.—The rock is clearly pyroclastic and owing to the presence of olivine would more properly be called a *basaltic tuff* rather than an *andesitic tuff*, as in the case of No. 101.

The large amount of quartz would presuppose an acid magma, far more acid than any which has ever been encountered in igneous rocks of this region. If this be considered a graywacke the quartz could naturally be segregated on the beach so as to give its present richness in silica. The slides show considerable variation in the size of the grains, but this has no special significance, save the fact that the material was derived close at hand.[4]

Plate V, fig. 2, is a photomicrograph of a similar rock but not from this precise spot.

BENGUET NO. 108.—FORAMINIFERAL LIMESTONE.

Macroscopic.—This is an aphanitic, pink-colored rock with conchoidal to hackly fracture, it contains a few veinlets filled with rusty calcite. The rock on its weathered surface has a dirty, bluish-gray appearance. It effervesces strongly with acids.

Microscopic.—Under the microscope the rock is seen to consist chiefly of large and small grains of calcite with almost every conceivable shape, stained copiously with iron oxide, which of course gives it its red color. The rock also contains the remains of the two well known Miocene fossils, *Operculina complanata* Bast. and *Lithothamnium ramossissimum* Ruess.

Plate V, fig. 1, is a photomicrograph of this rock.

Remarks.—I have found these same forms in limestones from Cebú Island, Polillo Island, Lepanto Province, Luzon, and other localities.

LIMESTONE FROM THE BENGUET ROAD.

Macroscopic.—In the hand specimen this rock is quite black, in portions very fine-grained, in others crystalline; it is occasionally streaked with minute calcite veins. It is very fossiliferous, but as the rock is very hard it is difficult to remove the fossils, which are for the most part large bivalves.

Microscopic.—The dark color is due to an excessive amount of iron oxide in the matrix. Large amounts of calcite in more or less rounded grains are to be seen in the slide, these practically make up the entire rock. Fragments of foraminifera are quite abundant, but, owing to their state of preservation we can make little more than a guess as to their identity. Some of these very much resemble sections of *Operculina* and there is another section which suggests a nummulite as it possesses "alar prolongations" between the successive whorls.

Remarks.—This limestone in its lithology, fossils, and position is quite different from the upper limestone on the Baguio Ridge. It would seem very probably to be Eocene.

BENGUET NO. 124.—FELDSPAR PORPHYRY.

Macroscopic.—A hypocrystalline, fine-grained, bluish-gray rock which has xenomorphic shape and hypautomorphic arrangement of its crystals. The rock is rather prominently speckled with small amphiboles or pyroxenes, difficult to separate in a megascopic examination.

Microscopic.—Another badly decomposed rock, consisting of phenocrysts of saussuritized plagioclase in a groundmass of small, lath-shaped feldspars, for the greater part plagioclases, and quite fresh magnetite grains, chlorite, calcite, etc. Besides the phenocrysts of feldspar, there are fragments of hornblende crystals, but in most cases there is little left of these, they having altered to both chlorite and serpentine.

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[4] Wavy extinction is to be seen in some of the quartz and feldspars. This means strain due to pressure. Also there is evidence of secondary enlargements of some of the minerals, another sign of metamorphic action.

Plate I, fig. 10, shows one section of the hornblende in this slide. The extinction is parallel and normal to the cleavage. However, this is a monoclinic amphibole and not an orthorhombic one. The pseudo-orthorhombic appearance is due to the section being cut from some plane normal to the plane of the optic axes from (100) or (001).

A very peculiar feature of these slides is the figure represented by the diagram Plate I, fig. 11.

Remarks.—What this form may have been originally is certainly open to conjecture.

APPENDIX.

Below are three analyses of rocks coming from this province, but unfortunately the hand specimens have been misplaced so that no descriptions can be made.

TABLE III.—*Benguet No. 17.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	An.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	47.94	799	12	144	380		72		25
Al_2O_3	21.96	216	2	24	190				
Fe_2O_3	2.48	016				16			
FeO	3.42	047				16	6	25	
MgO	6.83	171					30	141	
CaO	12.63	226			190		36		
Na_2O	1.49	024		24					
K_2O	0.19	002	2						
H_2O	2.38								
	99.32								

Constituent.		Norm.				
Quartz		.025	7.50	Q 7.50	Sal 74.07	
Orthoclase		.002	1.11	F 66.51		
Albite		.024	12.58			
Anorthite		.190	52.82			
Diop	Ca	.036	4.18	7.97	P 25.37	Fem 29.08
	Mg	.030	3.00			
	Fe	.006	0.79			
Hyp	Mg	.141	14.10	17.40		
	Fe	.025	3.30			
Magnetite		.016	3.71		3.71	

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 5. Corsase.
Subrang 5. (Persodic.)
(Luzonose?)

TABLE IV.—*Benguet No. 25.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	An.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	58.35	972	186	264	182		98	53	195
Al_2O_3	16.70	164	31	42	91				
Fe_2O_3	4.08	26				26			
FeO	3.28	45				26	9	10	
CaO	7.71	138			91		47		
MgO	3.29	82					38	44	
K_2O	2.87	31	31						
Na_2O	2.62	42		42					
F_2O	1.16								
	100.06								

Constituent.		Norm.				
Quartz		195	11.70	Q 11.70		
Orthoclase		031	17.24		Sal 78.28	
Albite		042	22.01	F 66.25		
Anorthite		091	25.30			
Diopide	Ca	047	5.45			
	Mg	038	3.8	10.44		
	Fe	009	1.19		P 16.16	
Hyp	Mg	044	4.4	5.72		Fem 22.55
	Fe	010	1.32			
Magnetite		026	6.03		M 6.03	
			100.14			

Remarks.—Microscopic examination shows this rock to be somewhat altered so that it is not well adapted to classification according to this system.

Class	II.	Dosolane.
Subclass	I.	Dosalone.
Order	4.	Austrare.
Rang	4.	Tonalase.
Subrang	2.	(Sodipotassic.) Harzose.

TABLE V.—*Benguet No. 120.*

Constituent.	Per cent.	Molecular proportions.	Orth.	Alb.	Am.	Mag.	Diop.	Hyp.	Quartz.
SiO_2	53.92	898	174	282	214		102	33	93
Al_2O_3	18.68	183	29	47	107				
Fe_2O_3	4.27	026				26			
FeO	2.65	037				26	7	4	
MgO	2.93	073					44	29	
CaO	8.85	158			101		51		
Na_2O	2.92	047		47					
K_2O	2.66	029	29						
H_2O +	2.33	148							
H_2O −	.44								
	99.55								

TABLE V.—*Benguet No. 120*—Continued.

Constituent.		Norm.				
Quartz		.093	5.58	Q 5.58	Salic 76.08	
Orthoclase		.029	16.12	F 70.50		
Albite		.047	24.63			
Anorth		.107	29.75			
Diop	Ca	.051	5.92	11.30	P 14.73	Femic 20.76
	Mg	.044	4.40			
	Fe	.007	.98			
Hyp	Mg	.029	2.90	3.43		
	Fe	.004	.53			
Mag		.026	6.03		M 6.03	
H_2O		.148	2.77			
			99.55			

Class II. Dosalane.
Subclass I. Dosalone.
Order 5. Germanare.
Rang 3. Hessase.
Subrang 2. (Sodipotassic)
(Baguiose?)[5]

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[5] The names Luzonose and Baguiose are offered merely as suggestive names.

ILLUSTRATIONS.

PLATE I. Line drawings, 11 figures.
II. Fig. 1, quartz diorite (No. 12) × 15, polarized light; fig. 2, quartz diorite (No. 153) × 15, polarized light.
III. Fig. 1, hypersthene-augite andesite (No. 106) × 9, ordinary light; fig. 2, andesitic tuff (No. 101) × 9, ordinary light.
VI. Fig. 1, andesite porphyry (No. 132) × 9; fig. 2, feldspar porphyry (No. 23) × 9.
V. Fig. 1, foraminiferal limestone (No. 108) × 15 approx.; fig. 2, graywacke (No. 127) × 10.

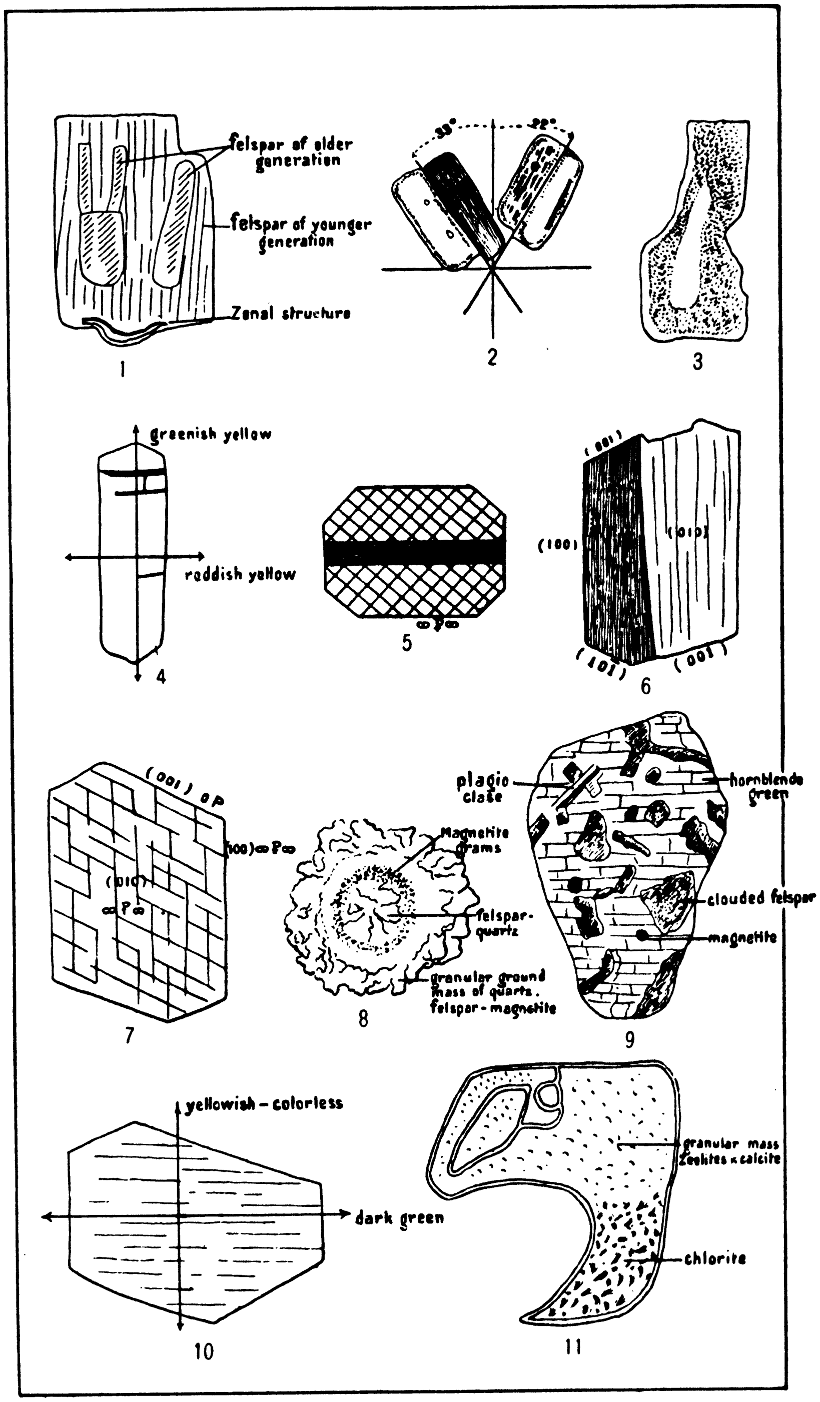
felspar of older generation
felspar of younger generation
Zonal structure
1
33°
22°
2
3
greenish yellow
reddish yellow
4
∞P∞
5
(001)
(100)
(010)
(101)
(001)
6
(001) oP
(100)∞P∞
(010)
∞P∞
7
Magnetite grains
felspar-quartz
granular ground mass of quartz, felspar-magnetite
8
plagioclase
hornblende green
clouded felspar
magnetite
9
yellowish-colorless
dark green
10
granular mass zeolites & calcite
chlorite
11

PLATE I.

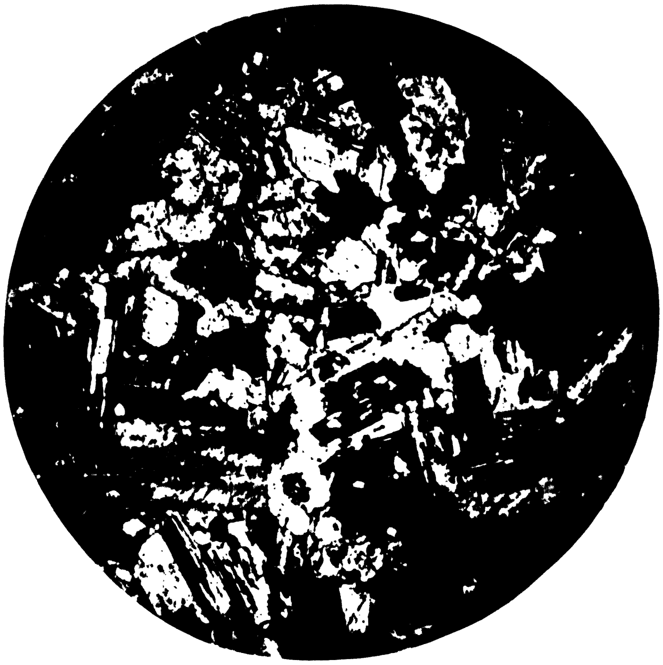

FIG. 1.

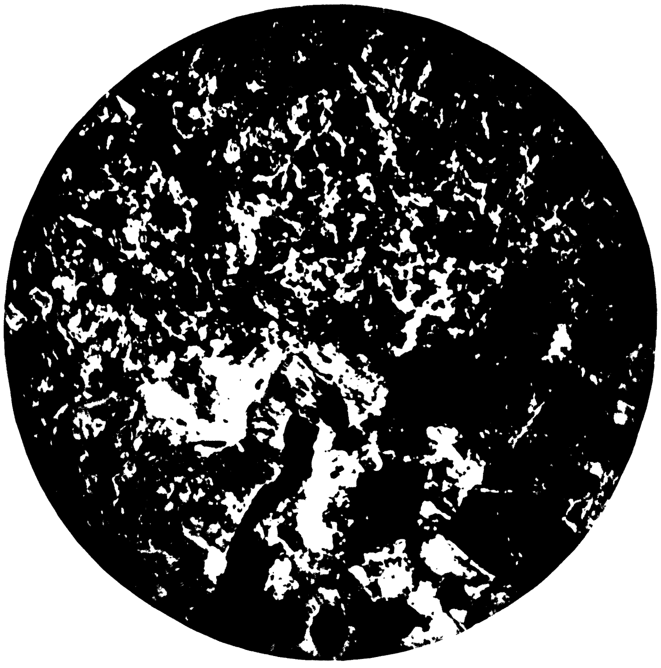

FIG. 2

PLATE II.

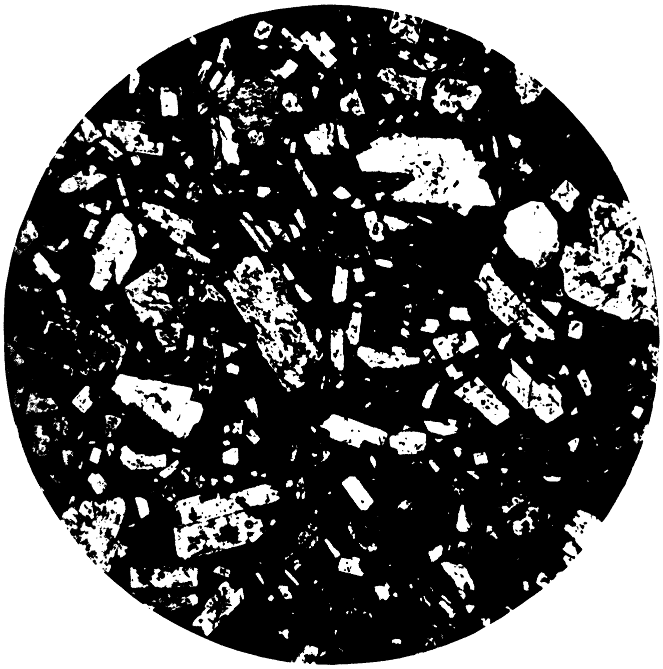

FIG. 1.

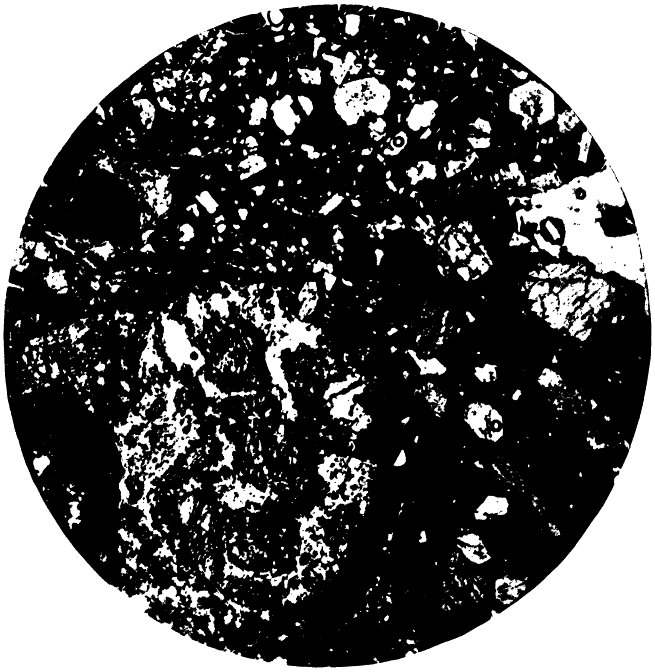

FIG. 2

PLATE III.

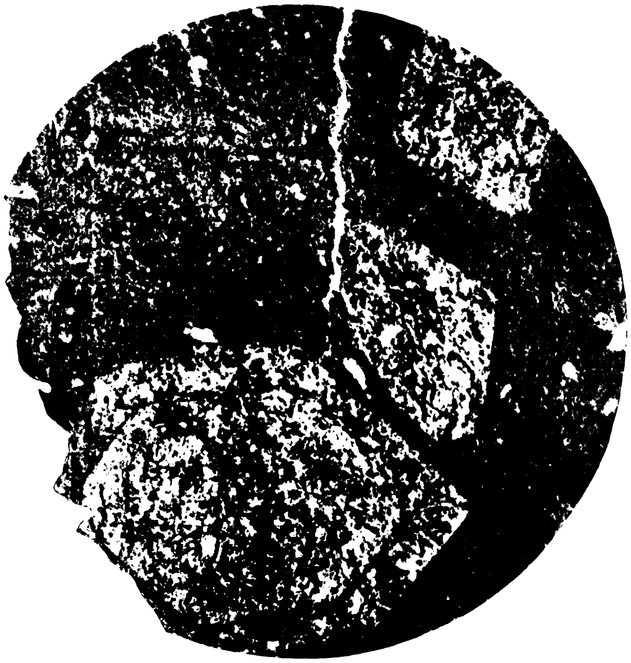

FIG. 1.

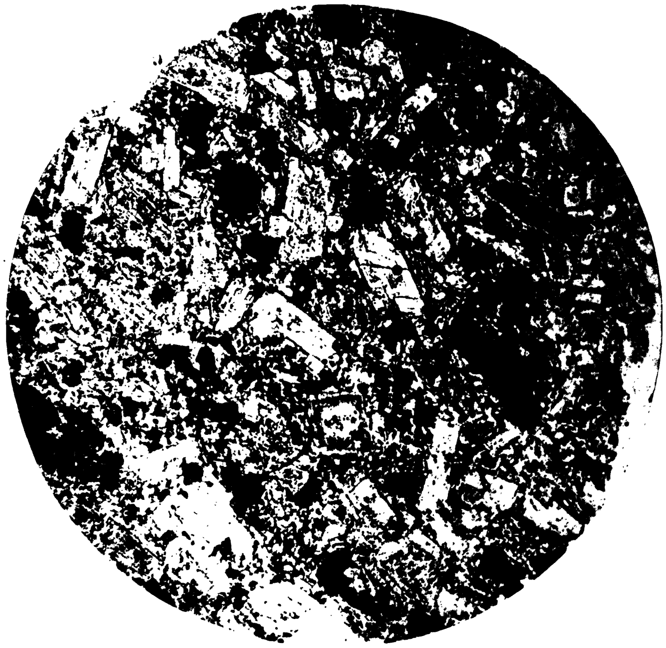

FIG. 2.

PLATE IV.

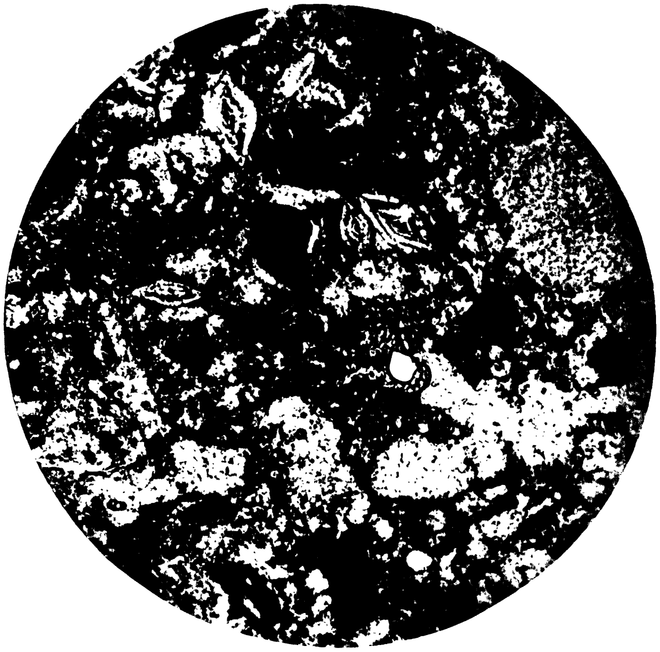

FIG. 1.

FIG. 2.

PLATE V.

REVIEWS.

An Elementary Study of Chemistry. By William McPherson, Ph. D. and William Edwards Henderson, Ph. D. Revised edition. Cloth. Pp. VIII+434. Price, $1.25. Boston: Ginn & Company, 1906.

This little text-book for beginning students in chemistry is the revision of a manual which has been used by several teachers during the past three years. The present work is this manual rewritten in the light of the criticisms offered by successful chemistry teachers, based upon their practical experience in its use. A very clear, accurate and practical text-book has been the result.

The book is throughly up to date. The theory of electrolytic dissociation is used throughout the book, being introduced in the ninth chapter, Solutions. The presentation of this theory, as of that of other theories used by chemists, is remarkably clear, the explanation being based on experimental facts with simple compounds with which the student is already familiar.

The same may be stated of the introduction to the law of mass action in Chapter XIII.

In discussing the methods employed commercially in the manufacture of chemical compounds, in all cases the most modern systems are cited. Thus we find described the methods of manufacture of phosphorus, carbon bisulphide, aluminium, sodium hydroxide, calcium carbide, graphite, bleaching solutions, the alkali metals, the artificial abrasives, etc., by the application of electricity.

The definition of steel as "the products of the Bessemer or open-hearth processes" appeals to a chemist as much more accurate than the definitions based on carbon content often found in small books. It might be remarked that such a definition would hardly include the tool steels manufactured directly from the ore in electric furnaces. But we can not expect a book of this size to be comprehensive. Another minor error noticed was the statement on page 399 that all the hydrocarbons of the methane series up to $C_{24}H_{50}$ are known. Probably the word normal has been omitted.

The reviewer considers this book as by far the best elementary textbook on chemistry which he has seen.

R. D. B.

A First Course in Physics. By Robert Andrews Millikan, Ph. D., and Henry Gordon Gale, Ph. D. Cloth. Pp. VIII+488. Price, $1.25. Boston: Ginn & Company, 1906.

This book is written as if it were the intention to make the laboratory work, which is given only in footnote references to a manual, teach the text rather than for the text to teach the laboratory work. Unlike many elementary physics the subject matter is presented in a logical and a thoroughly comprehensible manner. A distinctive feature is the excellence of the portraits and illustrations which are "in the fullest possible sense educative."

A. J. C.

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OSTEOLOGICAL AND OTHER NOTES ON SARCOPS CALVUS OF THE PHILIPPINES.

By R. W. SHUFELDT.
(*New York City.*)

INTRODUCTION.

About two years ago, Mr. Richard C. McGregor, of the Bureau of Science at Manila, roughed out two skeletons, both of adult females of *Sarcops calvus,* and sent them to me for description. The birds were taken in Mindoro in May, 1905. Shortly after receiving this material, I carefully prepared it for description. Dr. Charles W. Richmond, of the United States National Museum, courteously loaned me two skins from the collection of the Museum. One of these (No. 147229) was from Subic, Zambales, Luzon. The other (No. 190202) was taken at Pantar, Mindanao. These two specimens showed some distinctions in their markings, which if constant would seem to indicate that they were of different species. The gray mantle on the dorsum of the one from Luzon covered nearly the entire back, while in the one collected in Mindanao it was restricted to the region of the back of the neck. Believing that only one form of this bird was known to science, I communicated with Dr. Richmond and in reply received the following statement dated September 12, 1906:

> "In a recent number of the Bulletin of the British Ornithologists' Club, Grant has described a second species of *Sarcops,* and I think the Mindanao bird belongs to it, but I can not recollect what name he gave it."

Mr. W. de C. Ravenel, of the United States National Museum, wrote to me on August 17, 1905, as follows:

> "Dr. Richmond states that the sexes are alike in this species (*Sarcops*), and the specimens transmitted represent two phases of plumage (at one time thought to represent different species) regardless of sex."

Dr. Richmond also kindly furnished me with the following literature on the subject:

> "In reply to your inquiry of the 10th instant I beg to say that plates of *Sarcops calvus* are not very numerous in technical ornithological literature, but you may find some in the popular natural histories. There is a poor, colored plate in Daubenton's Planches Enluminées, No. 200, and a better one (but very small) in Kittlitz's Kupfertafeln der Vögel, Pl. XIII, fig. 2. Brisson Ornithologie, II, Pl. 26, fig. 2, is uncolored and poor.
>
> "The nearest relatives of *Sarcops* are *Basileornis* (from Celebes and Ceram), *Goodfellowia* (from Mount Apo, Mindanao; discovered in 1903), and the Minos (*Gracula vel Eulabes* Mino). *Basileornis* and *Goodfellowia* have graduated tails, like *Sarcops*, and are probably its closest relatives."

These relationships, of course, have been decided entirely upon external characters, as a complete account of the morphology of *Sarcops* has, as yet, never been given.

McGregor, in one of his published papers, lists this species as "*Sarcops calvus* (Linn)," the specimens having been taken at Romblon and Sibuyan, and he states that "a bird killed June 17 had a hard-shelled egg in the oviduct."[1]

I have not, in addition to the notes given above, especially looked into the literature of *Sarcops*, nor has it been deemed necessary to do so, as the present article has to do more particularly with a description of the skeleton of the species.[2]

Additional material, as follows, was received from Mr. McGregor just as I had commenced this paper:

Sarcops calvus, ♀ ad. Toledo, Cebu.
Sarcops melanonotus, ♂ ad. Basilan.
Oriolus chinensis, ♂ Basilan.
Lamprocorax panayensis, ♂ and ♀ ad. Toledo, Cebu.

Mr. McGregor states:

> "I can hardly hope to get you *Goodfellowia* as this species is found in Mindanao only. The bones of *Corone* and *Acridotheres* can be had with little trouble and I will try to send them before long."

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[1] McGregor, Richard C.: I. Birds from the Islands of Romblon, Sibuyan, and Cresta de Gallo. *Publications of the Bureau of Government Laboratories*, Manila (May, 1905) **25**, 16.

[2] I made a reduced photograph of one of the two skeletons in my possession, the reproduction of which is presented herewith. By comparing the proportions of this with some of the actual measurements given in this paper and taken from the specimen, a correct idea of the size of the birds may be gained.

I thought it possible that Professor J. B. Steere, of Ann Arbor, Michigan, the well-known authority on the birds of the Philippines, might have a skeleton of *Goodfellowia,* so I wrote to him and received the following reply:

> "I remember your kindness in looking over my manuscript of the Philippine Birds, but would be glad under any circumstances to aid you in your study of *Sarcops,* if I were able, but I am afraid I can be of little or no use. I never saw Hartert's genus *Goodfellowia.* I had supposed that the range of distribution of *Sarcops* pointed to its origin from Bornean or Celebes ancestors, though the genus is wanting in Palawan which is so closely related to modern Borneo. Though *Sarcops* is not a bird of long flights, it is so well distributed over the eastern and southern Philippines that it must be a form of long standing there, and long separation from its ancestral forms. I had always supposed, with no good reason perhaps, but the ordinary method of arranging the genera near each other in the books, that *Mainatus* or *Eulabes* was more closely allied to *Sarcops* than anything else in the Philippines, though the two genera do not overlap in distribution at all, I believe, *Eulabes* being found only in Palawan in the Philippines, and *Sarcops* being found everywhere else in the Philippines but in Palawan. The habits of the two genera are somewhat alike, as I remember them.
>
> "The Filipinos have a curious story to account for the bald head of *Sarcops.* As near as I can remember it, it runs as follows: 'Once *Sarcops* and the bush cuckoo, *Centropus,* made a bet as to which could fly highest. As they rose above the bushes the sun dazzled the eyes of the cuckoo and he dropped down again into the tall grass, saying '*Tig-sup*' (down I go), while the *Sarcops* kept on up until he struck the roof of heaven and knocked the hair off his head.' The Filipino language has but one word for hair and feathers, and the bush cuckoo still calls, and is called, *Tig-sup* (down I go). I am sorry I can be of no assistance to you."

OSTEOLOGY OF SARCOPS.

Although possessing the general characters of the skeleton as they occur in the *Passeres,* we have no passerine bird in this country with which *Sarcops* could with advantage osteologically be compared—that is, with the expectation of showing near relationships. Were this representative from the Philippines to be thus contrasted with an American species the most interesting genera for the purpose would be such forms as the yellow-headed blackbird (*Xanthocephalus xanthocephalus*), with its allies the redwings (*Agelaius*), the orioles (*Icterus*), and the grackles (*Quiscalus, Megaquiscalus*), especially the first mentioned. Osteologically, these birds have been described by me in several previous memoirs and papers, and these will be referred to in the course of the present examination. More remotely, or rather superficially, *Sarcops* may osteologically be compared with various species of the several genera *Pica, Cyanocitta, Aphelocoma, Xanthoura, Perisoreus, Corvus, Nucifraga, Cyanocephalus, Sturnus, Sturnella,* and *Euphagus,* skeletons of all of which I have in my private collection.

A casual glance at the skeleton of either *Sarcops calvus* or *S. melanonotus* is sufficient at once to satisfy the osteologist that it possesses all the general characters of a typical representative of the passerine group of birds, with many special ones that bring it very close to the forms in that assemblage more or less nearly related to the corvine type, and that it bears a somewhat similar relationship to *Corvus* or *Pica* as do the icterine genera mentioned above. These characters are immediately to be recognized in the skull, the bones of the pectoral arch, the sternum, and the pelvis—and, when this is the case, it is fair to presume that the vertebral column, the ribs, and the skeleton of the limbs form no exception.

The skulls in *Sarcops calvus* and *S. melanonotus* practically agree in all particulars, and to such a degree that it would be difficult to distinguish one from the other even in a long series of specimens. In making such comparisons the fact must be borne in mind that there may be marked differences in the skulls of different individuals of the same species, a good example of which I long ago pointed out in the case of *Xanthocephalus.*[3]

THE SKULL.

Viewing the skull of *Sarcops calvus* upon its superior aspect, it presents one very characteristic feature. This consists in the deep median furrow extending from the cranio-facial line backwards to be lost on the smooth, globular vault of the cranium in the parietal region. It is deepest between the midsuperior points of the orbital peripheries, and is due to the swollen condition of the latter, this being caused by the diploic tissue in the frontal bones in this locality. No such state as this is to be found in any of our icterine birds, or in the crows; it is entirely absent in *Oriolus chinensis*, and probably in other orioles. However, in some American forms of this genus, as in *Icterus cucullatus sennetti*, a shallow median depression may occur in the antero-frontal region, but without a thickening of the orbital rims upon either side. It seems quite likely then that this character alone would be sufficient to distinguish the skeleton of *Sarcops* from any of its near allies unless, peradventure, it be present in *Goodfellowia,* a species not yet examined by me osteologically. *Sarcops* has the parietal region of the skull smooth, full, and rounded, indicating a greater cranial capacity than in other icterine species of similar size, as for example, *Oriolus chinensis.* In this particular it approaches the crows and American marsh blackbirds and departs from the orioles, and such a species, too, as the huia bird (*Heteralocha gouldi*) of Australia—a form which Garrod found to be more nearly related to the *Sturnidæ* than to the *Corvidæ*.[4]

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[3] Shufeldt, R. W.: Individual variation in the skeletons of birds, and other matters. *The Auk.* July, 1887, 4, 265–268. (Letter to the Editor.) The two skulls illustrating this letter have appeared in several of my memoirs; the specimens themselves, however, are no longer in my collection, but were disposed of either to the British Museum or to the College of Surgeons (Lincoln's Inn Fields), London.

Passing to the lateral aspect of the skull, it is to be noted that *Sarcops* possesses the large, elliptical narial aperture found in the *Corvidæ*, the orioles, *Sturnella*, *Lamprocorax*, the American marsh blackbirds, and related genera and species. There is no osseous narial septum present, and in the material at hand I find such a bony partition developed only in *Oriolus chinensis* and *Corvus*,—to a slight degree, superiorly in the former, and anteriorly in the latter, as in the raven (*Corvus corax sinuatus*).[5]

In form, the superior mandible of *Sarcops* is rather broad at its base; the culmen rounded, tomia cultrate; the whole being gently decurved throughout and gradually carried to an acute apex anteriorly. (See Pl. I.)

More closely approaching the orioles in its general contour, it lacks entirely that peculiar median elevation of the culmen, between the nasals, so prominent in the skull of *Sturnella*, and generally in *Xanthocephalus*, *Agelaius* and their nearest relatives,[6] as well as in the several species of *Euphagus*, *Quiscalus*, *Megaquiscalus*, and somes finches most nearly related to them. The bone which I described as the lacrymal in *Sturnella* is also present in *Sarcops*, where it is represented by a small, triangular ossicle wedged in between the corresponding nasal and the pars plana, coming barely in contact with the frontal. Its descending spiral process may or may not ossify, but when it does, it supports, or gives attachment to, the thin membrane which anteriorly is attached to the maxillary below, and the free posterior margin of the nasal, anteriorly. Minute, insular ossifications may occur in this membrane, as I have found to be the case in *Sarcops melanonotus*. Indeed, the bone I take to be the lacrymal, in *Oriolus chinensis*, is very small, and it occupies a lower position between the pars plana and nasal, apparently not being in contact with the frontal at all, although it may articulate with its nasal process, beneath the overlapping nasal, and the relationship thus be concealed from view. This can only be proved by an examination of the nestling, before interossification of the bones involved has commenced. In fact, at this stage of development, in any of the species above mentioned, we may possibly discover that the ossicle I have considered to be the lacrymal is nothing more than an ossification in the upper angle of the triangular membrane stretched over the opening existing in the dried skull, between the pars plana, nasal, and maxillary, and that the true lacrymal in the adult is indistinguishably fused with the upper part of the pars plana. Such a discovery would not surprise me, but until such is shown to be the case, I must believe the above description to be the correct one.

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[4] Garrod, A. H.: Notes on the anatomy of the huia bird (*Heteralocha gouldi*) Proc. Zool. Soc. (1872), 643–647. Judging from the figures and description of the skull of this species, as given us by Garrod, *Sarcops* and it are by no means closely allied.

[5] Shufeldt, R. W.: The myology of the raven, p. 7, fig. 1. In some skulls of the common American crow at hand it is entirely absent, as it is also in *Pica*.

[6] Shufeldt, R. W.: On the skeleton of the genus *Sturnella*, with osteological notes upon other North American *Icteridæ*, and the *Corvidæ*. *Jour. of Anat. and Phys.* (1888), **22**, n. s., **2**, 311, Pl. XV, fig. 1. The form of the superior osseous mandible is far more like that which we find in *Pica*, it does not so much resemble that in *Sturnella* or the marsh blackbirds. In *Oriolus chinensis* there is a slight indication of this prominence of the culmen in the internasal region.

As in *Oriolus* and in the majority of the other species herein mentioned, the ethmoidal wing or pars plana in *Sarcops* in remarkably well developed. Apart from the two small foraminal perforations in it, it constitutes a complete, and rather thick, bony wall between the orbit and the rhinal cavity beyond it, being concave posteriorly and convex for its anterior surface, with a decided rounded notch at the middle of its external border—as in *Oriolus*, *Lamprocorax*, and others. This osseous partition is less complete in *Sturnella* and some of the crows. *Sarcops* possesses a capacious, hemispherical orbit, with quite a large vacuity in the interorbital septum, with the openings into the brain cavity much enlarged above, though the foramen rotundum remains distinct, though not as decidedly so as in *Cyanocephalus* and among the American jays.

As in *Oriolus chinensis,* the postorbital processes at the lateral aspect of the cranium are fairly well developed and bluntly pointed, the valley between them being narrow, rather deep and, extending backward as the crotophyte fossa, it is confined entirely to the lateral aspect of the skull. The conformation here agrees with the orioles rather than with the starlings and their near allies (*Sturnella,* etc.). The "infraorbital bar," composed of the usual bones, is extremely slender, hardly curved at all, and from quadrate to ethmoid, nearly of uniform size.

At the base of the skull all the bones and their articulations and relationships present the usual passerine characters, departing therefrom only in certain specific variations. Antero-posteriorly, the basitemporal region is short, and the sphenoidal rostrum sharply keeled beneath. The condyle is quite minute, while the subcircular foramen magnum is comparatively large. Nothing of special importance characterizes either the quadrates or the pterygoids. The body of a palatine is notably short antero-posteriorly, with the process at its postero-external angle conspicuous, though blunt, as in most orioles. Its prepalatine portion is very slender and widely separated from the fellow of the opposite side. In the intervening space is seen the large keeled and bifurcated vomer, which unites with the palatines posteriorly. A maxillo-palatine is an extremely delicate structure, with a slightly clubbed free posterior extremity. On either side, this very fragile little element curves backward in the space existing between the vomer and the prepalatine. There is no osseous floor to the rhinal chamber in front of the vomer—a partition that partly ossifies in *Oriolus*, but not in *Sturnella*.

At the posterior aspect of the cranium the occipital area is extensive and well defined, while the bounding crest is nowhere raised as it is in the American marsh blackbirds and the genus *Sturnella*—and in these latter forms, too, the occipital area comparatively is not so extensive. All this part of the skull in *Sarcops* is more as we find it in *Oriolus* and *Icterus*.

Concerning the mandible there is not much to be said, for it has the usual V-pattern of the various genera mentioned above, with a moderately deep symphysis and flat sides. As a whole the anterior moiety is bent gently downward, and an elliptical vacuity is to be found at its usual site in either ramus. Posteriorly, the articular ends are truncated, with an indication of a process above, each having the usual intumed one with the minute pneumatic foramen near the extremity. The inferior ramal margins are rounded, while superiorly beyond the symphysis they are cultrate. Upon either side, between the articular extremity and the corresponding quadrate a sesamoid is to be found. It occurs in the lateral ligament of the jaw, and is very likely to be overlooked in cleaning skulls of this species for study.

The sclerotal plates of either eye are small and of about the usual number. They present nothing peculiar beyond what we find in any ordinary passerine bird. This also holds true for the bones of the hyoid, for they possess the usual characters, although we must note that the uro-hyal has a spatulate distal extremity, present also in *Oriolus chinensis*. In the articulated skeleton, the inferior aspect of the ossified larynx rests upon this expanded portion of the mesial element of the hyoid.

REMAINDER OF THE AXIAL SKELETON.

Sarcops possesses an unusual number of vertebræ in its spinal column as compared with the other genera of birds named above. I find it to agree with the crows and jays, and such genera as *Molothrus* and *Calamospiza* in having 19 free vertebræ between the skull and the pelvis. All of the orioles (*Icteridæ*) and the marsh blackbirds which I have examined possess only 18. *Sarcops* has 11 vertebræ in its pelvic sacrum, that is that portion of the spine coössified with the ilia of the pelvis. In this count it agrees with most crows and jays found in the United States avifauna, orioles and marsh blackbirds (*Agelaius*, etc.) having but 10, as is also the case with *Euphagus* and *Sturnella*.

Finally, *Sarcops* has 7 free caudal vertebræ in addition to a large pygostyle. Only 6 tail vertebræ occur in the orioles, and other genera just named. In all these birds they appear to be nonpneumatic, and this also appears to be the case with the several vertebræ, while those of the neck and back are always pneumatic. *Sarcops* has a very rudimentary pair of free ribs on its thirteenth cervical vertebra, and a much longer free pair on the fourteenth; these latter, however, never have costal ribs or unciform appendages.

There are then 37 vertebræ and the pygostyle in the spinal column of *Sarcops;* the five dorsal ones bearing the dorsal ribs possess, as do all the others of the chain, the usual passerine characters. These ribs all support well-developed unciform appendages, and connect with the sternum by the intervention of a graduated series of costal ribs. The leading vertebra of the pelvis also has a pair of long, slender, free ribs, but this pair lacks the epipleural appendages, and its costal hæmapophyses, although long, fail to connect with the sternum. In the dorsal vertebræ the neural spines mutually interlock with each other, in front and behind, along their superior borders, while the anterior and posterior margins of these spines are concave and so do not come in contact with each other. The atlas vertebra has its articular cup perforated at its base, and the odontoid process of the axis vertebra is conspicuous. We note that in the case of the first six caudal vertebræ the transverse processes are very nearly of a uniform length, with pointed outer extremities. They are bent slightly downward, and their neural spines are about equally well developed. Only the fifth, sixth, and seventh caudals have hæmal spines, they being bifurcated in the last two—single, and hooked forward in the first. The seventh caudal vertebra is more or less rudimentary, more especially in regard to its lateral processes rather than its spines, in fact its bifurcated hæmal spine is the largest of the series.

Sarcops has a typically passerine sternum, and scarcely departs at all in its characters from the sterna of other birds more or less nearly related to it. *Oriolus chinensis,* for example, has a sternum almost identically like the bone as we find it in *Sarcops;* moreover, the sterna agree in the adult in the matter of length, to the fraction of a millimeter, the measurements being taken from the base of the bifurcation of the manubrium in front to the middle point of the xiphoidal border behind. The manubrial process is somewhat larger in *Sarcops* than it is in *O. chinensis,* otherwise they are identical and the sternum of *Sarcops* is so thoroughly passerine that it requires no special description. *Lamprocorax* forms no exception to this statement. As we know, even in the crows (*Pica, Corvus,* etc.) the sternum is practically the same in character—here, however, we meet with the pneumatic foramen mesially, in the coracoidal groove, posterior to the base of the manubrium, not found in *Sarcops* and others, wherein, nevertheless, the sternum is pneumatic.

Passing to the pelvis it is very obvious at a glance that in all particulars it, too, is typically passerine in each and all of its characteristics; so that what has just been said above in reference to the sternum is equally applicable to the pelvis. If we compare character with character as found in the pelvis of *Sarcops* with the corresponding ones in the pelvis of *Oriolus chinensis,* it is at once evident that the two bones are, morphologically, almost identical. As compared with its length, the width of the pelvis in *Sarcops calvus* is the mere fraction of a millimeter wider than is the case in *O. chinensis.* The same characters also obtain in any of our American orioles, such as *Icterus icterus, I. c. sennetti, Icterus spurius, I. galbala, I. bullocki,* and others with which I have compared it in this and other particulars. Even as we pass to *Euphagus,* the pelvis is of the same general pattern, which is likewise true of this bone in its near allies. In *Sturnella,* the mesial borders of the ilia in the dorso-preacetabular region of the pelvis usually meet the superior border of the sacral crista, a condition I have never met with in any of the other passerine birds named above.[7] It hardly seems necessary here to enter further into details of this bone, as I have so frequently figured and fully described the pelvis of corvine, sturnine, icterine, and related forms of birds, in other papers which have appeared during the past twenty-five years. It has already been pointed out above that there is one less vertebra included in the pelvis of *Oriolus* than there is in that of *Sarcops,* but this difference is only apparent after actual count, and in no way affects the general appearance of similarity in the bone in the two genera.

Coming to the bones of the pectoral arch or the shoulder girdle we find these, too, to be typically passerine in all their characters, and, moreover, remarkably alike in *Sarcops* and *Oriolus.* Essentially, too, they are the same in *Lamprocorax.* We meet with the usual U-shaped os furcula with its conspicuous, oblong hypocleidium extending backward but not coming in contact with the anterior margin of the carina of the sternum in the articulated skeleton. The clavicular limbs are slender, with the usual, expanded, free heads for articulation with the scapula and coracoid upon either side. These last two possess the usual passerine form, and articulate with each other and the furcula, exactly as they do in the *Icteridæ* and related genera.

At the shoulder joint in *Sarcops* and *Oriolus,* and probably in all the other genera mentioned, there is a free, peg-like os humero-scapulare of some considerable size.

SKELETON OF THE LIMBS.

There would be but little to be derived from a detailed description of the bones of the pectoral and pelvic limbs of *Sarcops,* for when it is said that they are typically passerine in all their essential characters, the comparative osteologist at once appreciates what they are like, morphologically. As compared with *Oriolus chinensis* the long bones of the arm or wing are both relatively as well as actually shorter in *Sarcops calvus* than they are in that species, the reverse being the case in regard to the bones of the leg. For example, in both of these birds the keel of the sternum has an extreme length of 3.4 centimeters while the proportionate length of some of the long bones is as follows:

---

[7] See fig. 7 of my memoir "On the skeleton of the genus *Sturnella,* etc. *Loc. cit.*

	Humerus.	Ulna.	Femur.	Tibio tarsus.	Metatarsus.
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*
Sarcops calvus	3.2	4	3.3	5.1	3.2
Oriolus chinensis	3.5	4.6	3	4.5	2.7

In *Sarcops* the humerus is highly pneumatic, and the ulna, to a degree, probably so. I am also inclined to believe that the femur and the proximal four-fifths of the tibio-tarsus is likewise so, while the other bones are not—certainly not the metatarsus and the bones of manus and pes.

The humerus has a straight shaft and short, radial crest. The pneumatic fossa is deep; completely surrounded by a raised rim, while the pneumatic foramen at the base is large, single, and leads directly into the hollow shaft. Both *Oriolus* and *Sarcops* have a fair sized free sesamoid at the elbow, an ossicle that is probably present in other species named above. In *Sarcops* the papillæ that usually are found down the shaft of the ulna are practically absent, while they are quite conspicuous in *Oriolus.* The bones of the carpus and pinion present nothing peculiar in either species.

The shaft of the femur is slightly bowed to the front in *Sarcops* and straight in *Oriolus,* while both possess a well-developed patella. Below the thigh bone the shafts of the tibio-tarsus and metatarsus are quite straight, especially in *Sarcops,* and the fibula extends only for a short distance below the articular ridge on the side of the shaft of the former. This ridge is more elevated in *Sarcops* than in *Oriolus,* thus causing the leg bones to stand farther apart in the former species.

Osteologically, the metatarsus and the pedal digits are normally passerine, and offer no salient characters by means of which they may be distinguished from the corresponding bones of the nearest allies of *Sarcops*—that is, beyond the matter of proportional size and lengths. The osseous claw or ungual phalanx of the hallux is very large in *Sarcops,* while the shaft of the proximal joint of this toe is comparatively slender. Beyond these few characters, there is nothing worthy of record, other than we would expect to find in the normal foot of a passerine bird of this size.[8]

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[8] Forbes, W. A.: On the variations from the normal structure of the foot in birds. *Ibis.* (1882), **6**, 386–390, fig. 1.

Comparing them character for character in all of their minor details, the bones of the limbs in *Sarcops* stand in better agreement with the corresponding ones in *Lamprocorax* than they do with those of *Oriolus*, and especially in the matter of those characters I have noticed above.

Further account of the osteology of the limbs of certain passerine birds more or less related to *Sarcops* are presented in my paper on the skeleton of *Sturnella*, cited above, and these may be compared by any one desiring such information, although this can only be considered of any taxonomic value whatever, when taken in connection with the characters presented on the part of the skulls and trunk skeletons of the various species considered.

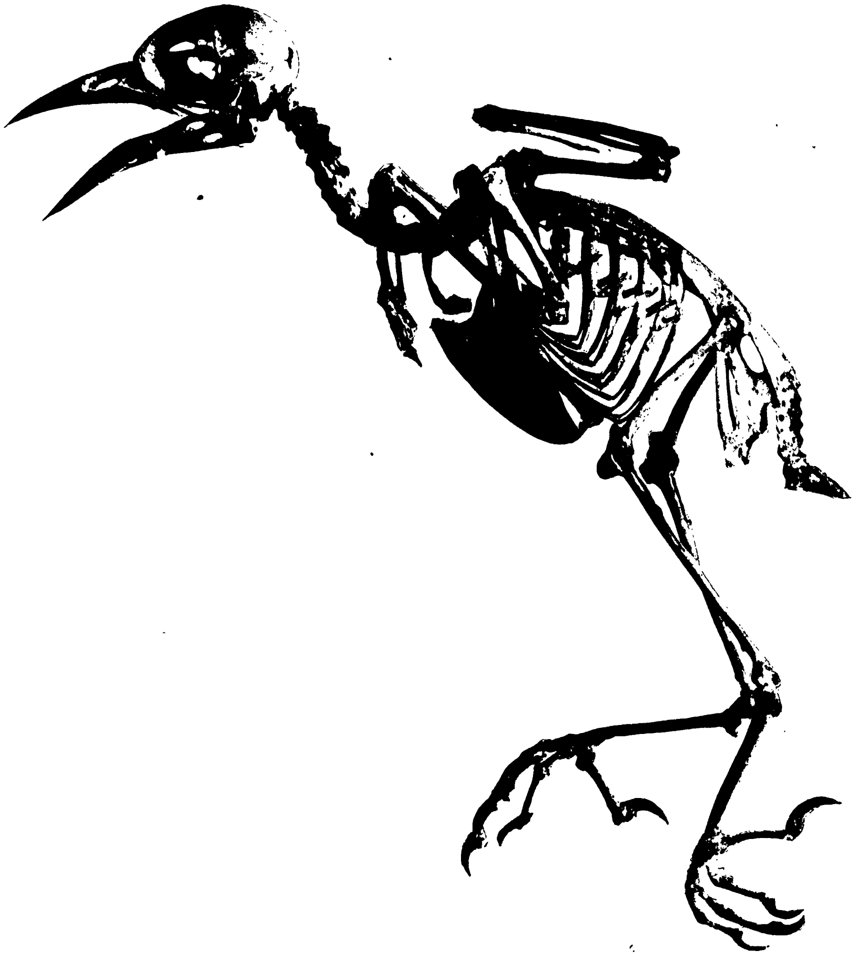
CONCLUSIONS.

Judging from the osteological characters of the material upon which the present examination is based it is clear that the representatives of the genus *Sarcops* are strictly passerine forms. In them the skull is very distinctive, and in a few particulars quite unlike any of the typical *Icteridæ*. This does not apply to the remainder of the skeleton. Unfortunately, *Goodfellowia* has not been compared osteologically in the present connection, but it may be said that in cranial characters *Lamprocorax panayensis* comes much nearer *Oriolus chinensis* than *Sarcops* approaches either of them. In fact, the skull in the latter is not particularly icterine in character, while in the morphology of the bones of its face it stands nearer the orioles than it does to species as the American marsh blackbirds, such as *Xanthocephalus* and its allies, although in other characters it approaches them.

It will require further examinations and comparisons with other related birds of the Philippine avifauna, and especially *Goodfellowia*, before a more definite opinion can be given as to the exact relationships of the species now included in this genus.

ILLUSTRATION.

PLATE I. Left lateral view of the skeleton of *Sarcops calvus*, adult ♀. Reduced about one-fourth. Hyoid arches removed, as well as the sclerotal plates of the eyes. Collected by Richard C. McGregor in Mindoro, May, 1905. From a photograph made by the author.



From a photograph by the author.

PLATE I. LEFT LATERAL VIEW OF THE SKELETON OF SARCOPS CALVUS. (ADULT ♀, REDUCED ABOUT ONE-FOURTH.)

ON A NESTING SPECIMEN OF CAPRIMULGUS GRISEATUS WALDEN.

By Dean C. Worcester.
(*From the office of the Secretary of the Interior.*)

On May 29, 1907, as I was riding over a piece of stony ground sparsely covered with vegetation, my horse stepped within six inches of a goatsucker (*Caprimulgus griseatus* Wald.) which was sitting on two eggs. The bird fluttered a scant two feet from her nest and lay quiet on the ground with her wings fully extended. After riding on for a short distance, I dismounted and returned to the nest. The bird allowed me to approach within five or six feet of her, and then attempted to toll me away by fluttering along the ground. After I had followed her for some distance she began to make short flights, doubling so quickly as she alighted that the eye could hardly follow her. Her color blended perfectly with the sand, gravel and stones about her so that in several instances, having looked away from her, I was quite unable to see her again until I walked up near enough to flush her.

On the following day I returned with a camera and took the photographs here reproduced.

The first (Pl. I, fig. 1) was taken at a distance of approximately ten feet; the second (Pl. I, fig. 2) at about five feet; the third (Pl. II, fig. 1) at thirty inches.

The bird at first was asleep, but while the camera was being set up for the third photograph with the lens close to her, she occasionally opened her eyes and was evidently depending upon her color to protect her.

Having secured the three photographs above mentioned, I endeavored to take a fourth from above, with the tripod directly over the nest. I succeeded in focusing without disturbing the bird; but the sunlight was intense and the flirting of the black cloth with which I was protecting the plateholder as I was about to insert the latter in the camera, caused her to take flight.

As on the previous day, she flew but a few feet at a time, at first alighting with wings outstretched and resting on the ground. As I followed her away from the nest, she increased the length of her flights, and again began to alight with a very swift doubling movement which rendered it most difficult for the eye to follow her.

After she had left her eggs I photographed them from above (Pl. II, fig. 2). They were two in number, and in color were dirty white with a few faint, purplish lines and blotches. They were in an advanced state of incubation. Scattered about near them were several small and perfectly white stones, which had evidently been brought from some distance by the parent birds, as no similar ones could be found in the vicinity. These stones served the purpose of rendering the eggs less conspicuous when uncovered, but whether they were brought with this end in view or for purposes of ornamentation, it is of course not easy to say.

ILLUSTRATIONS.

PLATE I.

FIG. 1. *Caprimulgus griseatus* on its nest; taken at a distance of ten feet.
2. The same at five feet.

PLATE II.

FIG. 1. The same at thirty inches.
2. The eggs of *C. griseatus* in situ; taken with the camera directly over the nest.

FIG. 1.

FIG. 2.

PLATE I.

FIG. 3.

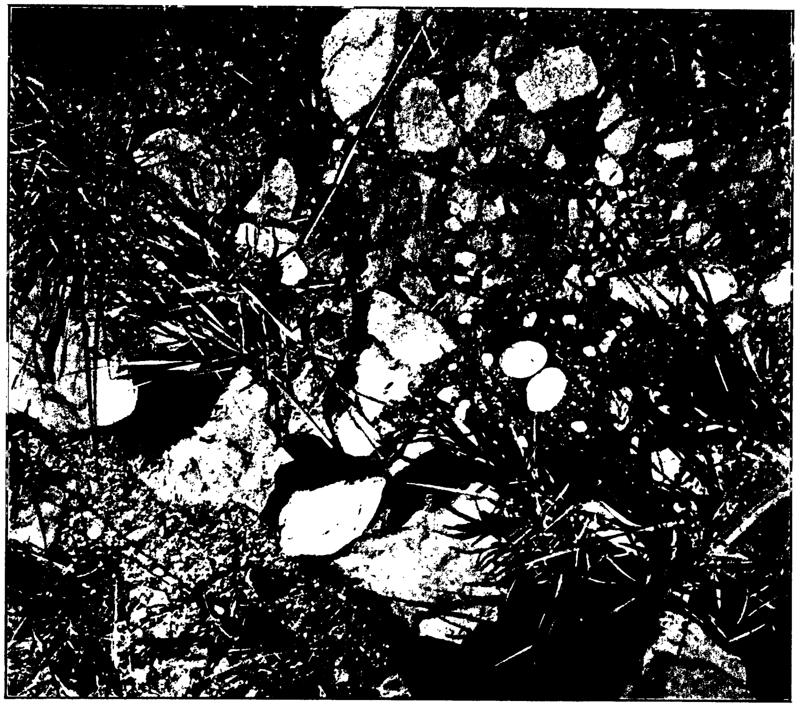


FIG. 4.

PLATE II.

ON A NESTING PLACE OF SULA SULA (LINNÆUS) AND STERNA ANÆSTHETA SCOPOLI.

By DEAN C. WORCESTER.

On Saturday, June 15, 1907, when on a trip of inspection to the Babuyanes and Batanes Islands in company with the Governor-General, our party sailed from Port San Pio on the Island of Camiguin in a general northwesterly direction in order to observe a volcano said to exist in the immediate vicinity of the Didikas rocks.

We found that this volcano, which rose from the sea in 1859 and gradually increased in size until it attained a height of 700 feet, had completely disappeared.

The Didikas rocks consist of three separate masses, two of which rise to a height of about 150 feet each and are quite sharply pointed, while the third mass is longer, lower, and runs up to a narrow crest (Pl. I). There were signs of recent volcanic activity on the western side of this lower mass of rock; and as the sea was perfectly calm at the time, we attempted to land in order to make a closer examination. As our boat approached the rocks large numbers of boobies [*Sula sula* (Linn.)] and terns (*Sterna anœstheta* Scop.) flew out to meet us and hovered about our boat in evident curiosity. They were little disturbed by the shots that ended the earthly careers of several of their number, and continued to follow us about as long as we remained in the immediate vicinity of the rocks.

The two higher pointed rocks were covered with the excrement of the boobies, and as a number of terns were seen issuing from holes in the volcanic conglomerate which made up a part of the third rock, it seems probable that both species use these rocks as a nesting place.

The Didikas rocks lie fairly in the main typhoon track and are swept by fierce winds and strong currents. There is no more isolated and inaccessible breeding ground for water-birds in the Philippine Islands. Even with the sea apparently perfectly calm, it proved impossible to land, as the almost imperceptible swell was breaking so heavily at the base of the rocks that there would have been serious danger of destroying our boat had we attempted to do so.

ILLUSTRATION.

PLATE I. View of Didikas rocks.

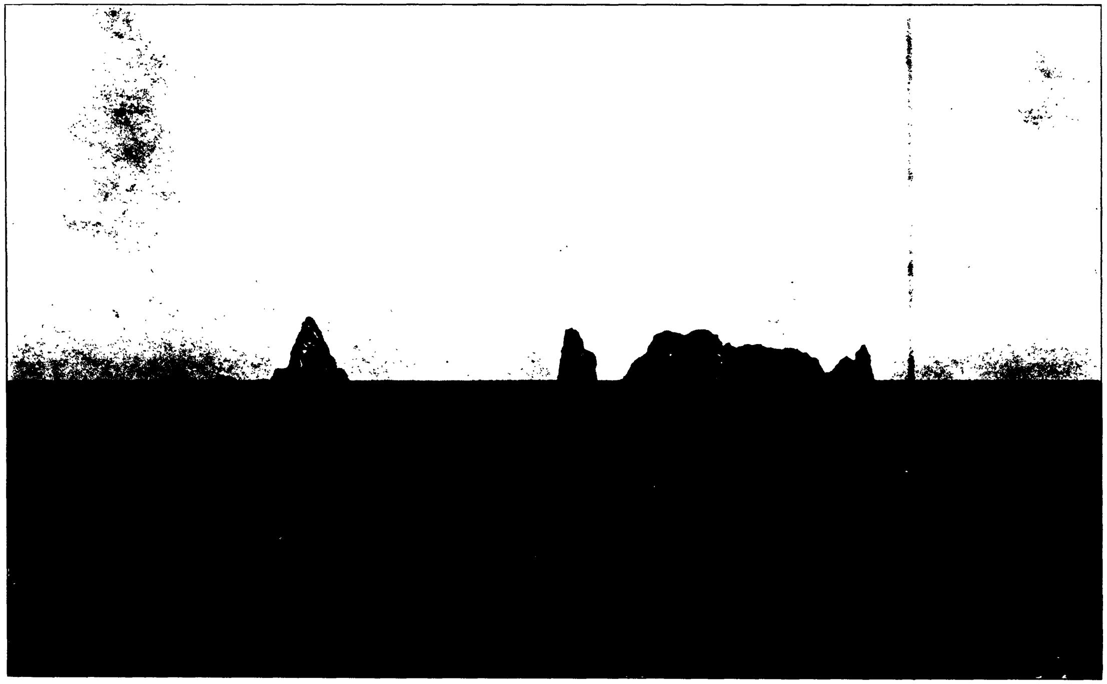


PLATE I.

NOTES ON A COLLECTION OF BIRDS FROM THE ISLAND OF BASILAN WITH DESCRIPTIONS OF THREE NEW SPECIES.

By RICHARD C. McGREGOR.

(*From the zoölogical section, Biological Laboratory, Bureau of Science.*)

The Island of Basilan is about 8 miles south of the long peninsula of Mindanao on which Zamboanga is situated. It is separated from Mindanao by shallow water and there are several small islands in the channel. Basilan is well wooded and its surface is broken, but there are no high mountains. The small island of Malamaui is separated from Basilan by so narrow a channel that I have not thought it worth while to consider the two islands as distinct localities.

Steere visited Basilan in 1874 and obtained 23 species of birds, 14 of which were described by Sharpe. Everett spent a short time there in 1878 and added 48 species to the list. The Steere Expedition in November, 1887, obtained specimens of 8 species which were described as new by Steere. In 1890 the Menage Expedition made a large collection in Basilan, adding 15 species to the list of those already known from the island; one of these was new to science. The species known from Basilan as given in McGregor and Worcester's Hand-List amount to 122, but one of these (*Callisitta œnochlamys*) is not found in the island, so that 121 is believed to be the correct number.

Collectors from the Bureau of Science worked near Isabela, Basilan, from December 14, 1906, to March 19, 1907, and the specimens obtained by them furnish the material for this paper. I am now able to add 29 species to the list of Basilan birds, one of which appears to be new to science. At the same time I have described, as new, two species which have previously been united with their relatives found in Mindanao.

LIST OF SPECIES NOT PREVIOUSLY RECORDED FROM BASILAN.

Excalfactoria lineata.
Rallina euryzonoides.
Gallinula chloropus.
Charadrius fulvus.
Ochthodromus mongolus.
Ægialitis dubia.
Ægialitis peroni.
Himantopus leucocephalus.
Totanus eurhinus.
Heteractitis brevipes.

LIST OF SPECIES NOT PREVIOUSLY RECORDED FROM BASILAN.—Cont'd.

Rhyacophilus glareola.
Limonites damacensis.
Dissöura episcopus.
Ardea sumatrana.
Egretta garzetta.
Bubulcus coromandus.
Dendrocygna guttulata.
Mareca penelope.
Astur, sp.
Astur soloensis.
Cuculus canorus.
Chalcococcyx xanthorhynchus.
Chalcococcyx malayanus.
Pitta fastosa, new species.
Hemichelidon griseisticta.
Pericrocotus cinereus.
Locustella ochotensis.
Acanthopneuste borealis.
Budytes leucostriatus.

LIST OF NEW SPECIES.

Thriponax multilunatus.
Pitta fastosa.
Orthotomus mearnsi.

TITLES OF PRINCIPAL PAPERS ON THE BIRDS OF BASILAN.

Bourns and Worcester, Preliminary notes on the birds and mammals collected by the Menage Scientific Expedition to the Philippine Islands. *Minn. Acad. Nat. Sci., Occ. Papers* (1894), **1,** 1–64.

McGregor and Worcester, A hand-list of the birds of the Philippine Islands. *Publications of the Bureau of Government Laboratories* (1906), **36,** 1–123.

Sharpe, Prof. Steere's Expedition to the Philippines. *Nature* (1876), **14,** 297–98.

Sharpe, On the birds collected by Professor J. B. Steere in the Philippine Archipelago. *Trans. Linn. Soc. Zool.* (1877), **1,** 307–355, pls. 46–54.

Steere, A list of the birds and mammals collected by the Steere Expedition to the Philippines. Ann Arbor (July 14, 1890) 1–30.

Tweddale, On the collection made by Mr. A. H. Everett in the Island of Basilan. *Proc. Zool. Soc.* (1879), 68–73.

Worcester, Notes on the distribution of Philippine birds. *Proc. U. S. Nat. Mus.* Wash. (1898), **20,** 567–625, pls. 55–61.

Worcester and Bourns, A list of the birds known to inhabit the Philippine and Palawan Islands, showing their distribution within the limits of the two groups. *Proc. U. S. Nat. Mus.* Wash. (1898), **20,** 549–566.

NOTES ON THE SPECIES OBSERVED.

Megapodius cumingi Dillw.

This megapode appeared to be rare in Basilan; a live specimen was seen which had been taken in a snare.

Excalfactoria lineata (Scop.).

A male was taken February 6; the species is not common in Basilan and so far has been unrecorded from the island.

Gallus gallus (Linn.).

The jungle fowl was rather abundant in thick second growth on Malamaui and several individuals were killed.

Osmotreron axillaris (Bp.).

A female was taken March 13.

Osmotreron vernans (Linn.).

This species like the last was not common; a female was taken in December.

Phapitreron brunneiceps Bourns & Worcester.

This species is very distinct from *P. amethystina*, being smaller and differently colored. A male taken February 28 yields the following measurements: Length, 10.5 inches; wing, 5.32; tail, 3.94; culmen from base, 0.98.

Phapitreron occipitalis Salvad.

Fairly abundant; bill and bare skin about eyes, black; irides light-purple; feet deep rose; nails gray. This species is well separated from *P. leucotis* by its lighter chin and malar region and by its much shorter wing; it seems to be very near *P. brevirostris* but it has more metallic color on head and neck than the latter species.

Leucotreron occipitalis Bp.

A male in adult plumage has albinistic feathers in mantle, back, tail, and wings.

Spilotreron bangueyensis (A. B. Meyer).

This handsome little dove was abundant and specimens collected were very fat. It was found feeding on the fruit of small, second growth trees and shrubs.

Muscadivora æenea (Linn.).

Several specimens killed.

Zonophaps poliocephala (Hartl.).

This large zone-tailed pigeon is represented by a female taken March 15.

Macropygia tenuirostris Bp.

The slender-billed cuckoo-dove is represented by a female taken in December.

Streptopelia dussumieri (Temm.).

Not common.

Chalcophaps indica (Linn.).

A female was taken in January.

Phlogœnas crinigera (Jacq. & Pucher.).

But three specimens of this species obtained. Length, 10.8 to 11.5 inches; bill, black; irides dark-blue; legs and feet flesh; scales dark carmine; nails white.

Rallina euryzonoides (Lafr.).

A male of this rail, which has not been recorded from Basilan, was taken February 22.

Poliolimnas cinereus (Vieill.).

An immature male was taken December 26.

Amaurornis phœnicura (Forster).

A pair taken December 21.

Gallinula chloropus (Linn.).

A female was taken December 29 and several other individuals were seen; the species has not been previously noted from Basilan.

Charadrius fulvus (Gm.).

Two specimens were preserved and others were seen during December; the species has not been recorded from Basilan.

Ochthodromus mongolus (Pallas).

A female plover, taken December 20, is of this species which is new to the Basilan list.

Ægialitis dubia (Scop.).

A male specimen of this small plover was taken January 3 and the species is new to the Basilan list.

Ægialitis peroni (Bp.).

A female was taken December 16; like the last this species has not been recorded from Basilan.

Himantopus leucocephalus Gould.

A solitary bird, which I have no hesitation in referring to the above species, was repeatedly seen on Malamaui; this species has been recorded from Mindanao and so far from no other island in the Philippines.

Totanus eurhinus (Oberh.).

A female of this species was taken December 29; the species has not been recorded from Basilan.

Heteractitis brevipes (Vieill.).

A female was taken December 12; this species appears not to have been recorded from Basilan.

Rhyacophilus glareola (Gm.).

This species, which was fairly common, seems to be unrecorded from Basilan; specimens were obtained in December.

Limonites demacensis (Horsf.).

Small flocks of stints were found about old, flooded rice-fields on Malamaui; a male and two females taken December 26 are of this species, which is an addition to the Basilan list.

Gallinago megala Swinhoe.

Snipe were abundant about the duck pond on Malamaui and the only specimens killed were of the above species.

Dissöura episcopus (Bodd.).

This stork was seen in flight and resting in small trees near the town of Isabela; the species has not been noted as an inhabitant of Basilan.

Ardea sumatrana Raffl.

A female was taken December 18. One, of two fish extracted from its gullet measured 3.5 inches in depth. This species of heron is an addition to the Basilan list.

Egretta garzetta (Linn.).

A male taken December 20 measured 24 inches in length; legs, blackish with blotches of green on upper parts; feet and lower part of tarsi, green; bill, black, except basal half of lower mandible which was white. This is the first record of the species from Basilan.

Butorides javanica (Horsf.).

Common in mangrove swamps.

Bubulcus coromandus (Bodd.).

A few small flocks observed and a female taken in December. This species is new to the Basilan list.

Ardetta cinnamomea (Gm.).

Fairly abundant; an immature female was taken December 29.

Dendrocygna arcuata (Horsf.).

A few ducks, for the most part of this species, were observed on a small pond in Malamaui.

Dendrocygna guttulata Wallace.

A male of this species was found in a string of *D. arcuata* killed December 26; the species has not been previously noted in this locality.

Mareca penelope (Linn.).

A female widgeon in very poor plumage was taken January 5. The only previous Philippine record is based on a specimen killed by me in Calayan.

Fregata species.

On January 17 a small flock of frigate pelicans was seen near Basilan.

Astur species.

A female taken January 24 is provisionally identified as *Astur trivirgatus.*

Astur soloensis (Lath.).

Specimens were obtained in January, February, and March.

Spilornis holospilus (Vig.).

Two specimens taken.

Butastur indicus (Gm.).

A female taken January 31.

Haliaëtus leucogaster (Gm.).

Occasionally seen.

Haliastur intermedius Gurney.

A few seen.

Ninox japonica (Temm. & Schl.).

A male and a female taken in Basilan, February 27, are darker than specimens from Cuyo and Calayan. The following notes indicate the variations in specimens at hand.

Basilan, February, male and female; six dark tail-bands, first and second primaries with no light bands, third and fourth slightly banded.

Cuyo, March, male; four tail-bands, all primaries strongly banded.

Fuga, August, two males; five tail-bands, all primaries banded.

Calayan, November, male; five tail-bands, and primaries strongly banded; December, male and November, female; five tail-bands, first primary with indications of light bands.

Hondo, Japan; five tail-bands, all primaries weakly spotted.

Ninox spilocephala Tweed.

Five specimens were taken in February and March. This species is very much like *Ninox philippensis* but is easily recognized by its spotted head.

Cacatua hæmaturopygia (P. L. S. Müller).

Abundant.

Prioniturus discurus (Vieill.).
Abundant; feeding on bananas.

Tanygnathus lucionensis (Linn.).
Abundant.

Loriculus apicalis Souancé.
Fairly abundant.

Batrachostomus septimus Tweed.
A pair of frog-mouths taken March 1 are in perfect rufous plumage. These specimens agree fairly well with the description of the above species.

Eurystomus orientalis (Linn.).
The oriental roller was seen in its usual numbers.

Pelargopsis gigantea Walden.
A female taken December 20.

Alcedo bengalensis Briss.
Abundant.

Ceyx mindanensis Steere.
A number of specimens of this species taken in February and March.

Ceyx bournsi Steere.
Several specimens taken.

Halcyon winchelli Sharpe.
Fairly abundant.

Halcyon chloris (Bodd.).
Abundant.

Hydrocorax mindanensis (Tweed.).
Several specimens secured.

Penelopides basilanica Steere.
Abundant.

Merops philippinus Linn.
Two males collected.

Lyncornis macrotis (Vig.).
A male from Basilan can be almost exactly matched by birds from Luzon and Mindoro. This species seems to be somewhat dichromatic and in the series of fifteen specimens before me the dark, brown-headed form is the commoner. The variation from this is most strongly marked in a female from Lamao, Bataan Province, Luzon, collected January 3, 1905. The forehead and top of head are light rusty-fulvous with fine, blackish vermiculations and the black spots on vertex are much reduced in size; the jaws, sides of face, ear-coverts and supercilia are rufous with black cross-lines; in the commoner type these parts are black with narrow rufous cross-lines. The same general condition extends to the wings and coverts, namely an increase of rufous at the expense of the black. The light areas of the scapulars which are normally white or nearly white, are fulvous in the rufous phase. The light tail-bars are more pronounced and are nearly entire across the webs, instead of being greatly broken. The under surface of the body is similar to that of the normal type except the fore-breast which is more strongly vermiculated with rufous.

Macropteryx major Hartert.
Two specimens secured.

Chætura species.

A large swift, presumedly *C. celebensis*, was frequently seen.

Pyrotrogon ardens (Temm.).

Specimens from Basilan have much larger bills than specimens from Luzon but the colors are exactly similar.

Surniculus velutinus Sharpe.

Three males obtained in January and February.

Cuculus canorus Linn.

A male in good plumage was killed December 27; this species is new to the Basilan list.

Cacomantis merulinus (Scop.).

Fairly abundant.

Chalcococcyx xanthorhynchus (Horsf.).

An adult male was taken January 9; both this and the following species are unrecorded from Basilan.

Chalcococcyx malayanus (Raffl.).

An immature male was taken December 26; length 6.5 inches; irides and eyelids, red; bill and feet, black. A female taken December 31 has throat, breast, and sides of neck heavily washed with rusty-brown; length 6.3 inches; irides, red; bill, black; base of bill, dark red; feet, dark green.

Eudynamis mindanensis (Linn.).

A male taken March 18.

Centropus viridis (Scop.).

A few seen.

Centropus melanops Less.

The black-eyed cuckoo occurs in some abundance in Basilan; there is considerable variation in the size of bill in this species, but it is purely individual. Birds from Basilan and Bohol do not differ in coloration.

Thriponax multilunatus sp. nov.

Specific characters.—Similar to *Thriponax javensis* but the white lines on throat wider and feathers of fore-breast narrowly edged with pale-fawn or buffy-white, forming crescentic marks, this approaching *T. pectoralis.*

Type.—No. 6171, ♂, Bureau of Science Collection; Isabela, Island of Basilan, P. I., December 28, 1906; R. C. McGregor and A. Celestino.

Description of type.—Forehead, crown, crest, and malar stripe bright-crimson, the feathers withish at base; nasal plumes, blackish; lores and a wide transocular band black; rest of upper parts, wings, and tail, black; second, third, and fourth primaries with a white spot at base of inner web; third to seventh primaries with a white spot at tip of outer web; inner secondaries white at base; chin, throat, and postauricular area, black, each feather narrowly margined with whitish, producing a striped appearance; breast, black, the feathers of fore part narrowly bordered with buffy producing a series of crescentic light marks; abdomen and sides, buffy white; thighs black, each feather widely bordered with light buff; vent and tail-coverts, black. Length in flesh, 16.5 inches; wing, 8.25; tail, 6.55; culmen from base, 2.05; tarsus, 1.16.

Ten specimens from Basilan differ uniformly from *Thriponax javensis* and maintain the specific characters assigned above. That the crescentic breast marks are not due to immaturity is evident from an examination of young specimens of *T. javensis* from Luzon for these have the breast entirely black.

Yungipicus fulvifasciatus Hargitt.

This small woodpecker is a common species in Basilan.

Chrysocolaptes lucidus (Scop.).

Abundant.

Sarcophanops steerei Sharpe.

A large series of this curious species was obtained. A male and a female, taken January 23 and March 1 respectively, are immature and differ from the adult as follows: Throat, white, the black confined to chin and sides of throat except a few black feathers; under tail-coverts, tinged with brown; top of head, blackish, forehead, washed with yellow, some of the adult feathers present; back and wing-coverts, dark slate-gray widely edged with olive-green; yellow wing bar paler, the white portion washed with buff; the young male differs from the young female in having a few pale-lavender feathers on throat and breast.

Pitta fastosa sp. nov.

Specific characters.—Similar to *Pitta moluccensis* P. L. S. Müller but vertical stripe black not dark brown.

Type.—No. 11,900, ♀, Bureau of Science Collection; Island of Basilan, P. I.; February 9, 1907; Celestino and Canton.

Description of type.—Sides of head including lores, cheeks, supercilia, and ear-coverts black connected by wide black collar; wide vertical stripe black, bordered on each side by a wide stripe of fulvous brown, the feathers edged with pale-buff on exterior webs; back, scapulars, and tertiaries dark green; rump, upper tail-coverts, and lesser wing-coverts bright ultramarine-blue; chin, black; throat, white; lower throat, breast, abdomen, and flanks ruddy-buff, most intense on breast; vent, under tail-coverts, and middle of abdomen bright-red; tail, black tipped with dull-blue; primaries black, each feather with a white patch, mesial and smallest on first, reaching tip on seventh; secondaries, black, edged with dull blue on terminal half; alula, primary coverts, axillaries, and wing lining black. Length in flesh, "7.5" inches; wing, 4.65; tail, 1.58; culmen from base, 1.10; bill from nostril, 0.72; tarsus, 1.44.

The type and only specimen was secured near the town of Isabela. Oates[1] states that *Pitta moluccensis* is found in the Philippines but Walden[2] makes no remarks on the species in his review of Philippine ornithology and none of the more recent collectors has taken it.

Pitta erythrogaster Temm.

A young male was taken March 7.

Pitta atricapilla Lesson.

Several specimens.

Hirundo javanica Sparr.

This swallow was building nests in December and January.

Hemichelidon griseisticta (Swinh.).

A female was collected January 15 and this species is new to the Basilan list.

Cyornis philippinensis Sharpe.

A female was preserved.

Muscicapula basilanica (Sharpe).

One female specimen.

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[1] Oates: Bds. of British Burmah (1883), **1**, 416.

[2] *Trans. Zool. Soc.* (1875), **9**, 187–89.

Hypothymis occipitalis (Vig.).

A male in fine plumage was taken January 16; numerous other individuals were seen.

Hypothymis superciliaris Sharpe.

This species was fairly abundant and several specimens were taken.

Cyanomyias cœlestis (Tweed.).

Fairly abundant and usually found in company with the last two species. In a male taken February 2 the longest crest feathers measure 1.5 inches. The male taken by me near Mariveles, Luzon, differs in no way from Basilan specimens.

Rhipidura nigritorquis Vig.

A common species.

Zeocephus cinnamomeus Sharpe.

This race appears to differ very little from *Zeocephus rufus*, but fully adult individuals are believed to be quite distinguishable. I will here transcribe pertinent MS. notes by Worcester and Bourns: "We have some suggestions to offer, after looking over our series of thirty-one specimens from Luzon, Mindoro, Panay, Negros, Cebu, Basilan, Sulu, and Tawi Tawi. The immature birds of *Z. rufus* have the white belly and general coloring of *Z. cinnamomeus*. They are not to be distinguished from birds of the latter species. Second, out of fifteen specimens from the south, seven do not show a trace of white on the belly, and are of a uniform deep rufous color. Third, we have a male bird in breeding plumage from Cebu which is indistinguishable, so far as shade of rufous is concerned, from Basilan birds. The confusion between the two species is thus readily understood. Are they then distinct? We think they are for the following reasons. The average fully adult bird from the northern islands is very much darker in color than the darkest of the southern birds. The northern birds have the tail much more strongly graduated than that of the birds from the south. None of our specimens from the south show any special elongation of the central tail-feathers. The northern birds in good plumage all have the central tail-feathers decidedly elongated. In one specimen from Tablas and another from Sibuyan the central tail-feathers exceed the rest by full three inches. Other birds, collected at the same time and place do not show nearly so strong a development of these feathers, but the fact remains that nothing even approaching it is shown by our specimens from the south.

"The dark tips of the tail-feathers described by Dr. Sharpe as characteristic of *Z. cinnamomeus* are simply a sign of immaturity, as is the white of the belly.

"*Zeocephus rufus*, then, inhabits the northern and central Philippines, and is to be distinguished from *Z. cinnamomeus* by its darker color when fully adult, and by its more strongly graduated tail, which has the central tail-feathers at least three inches longer than the others when the birds are in perfect plumage. A male from Sibuyan with elongated central tail-feathers measures *11.25 inches in length; tail, 6.40*."

I may add that a male collected by me in Sibuyan June 28, 1904, was 12 inches in total length and the tail measures 7.45, the central feathers exceeding the others by 3.38.

Abrornis olivacea Moseley.

A female taken December 31 does not differ from a female taken in Bohol.

Rhinomyias ruficauda (Sharpe).

Fairly abundant in forest.

Artamides kochi Kutter.

An abundant species. In some female skins the black bars of under tail-coverts are almost entirely wanting. Specimens from Bohol and from Basilan are specifically identical and differ in no way.

Edoliisoma mindanense (Tweed.).

Numerous specimens from Basilan agree with the description of the type from Mindanao and are doubtless identical with the above species. Birds in young banded plumage were taken January 12 and 19 and March 7. *Edoliisoma elusum* is found to be quite distinct from this species. In the male of *E. mindanense* the rump and upper tail-coverts are pale-gray, the coverts tipped with white, while in the male of *elusum* the back, rump, and tail-coverts are uniform. The females of the two species differ in the same way and in addition the female of *mindanense* has the abdomen and under-tail coverts very pale-gray, almost white, while in the female of *elusum* the under parts are uniform slate-gray.

Pericrocotus cinereus Lafr.

Two specimens of the ashy minivet were secured February 18; this appears to be the most southern point in the Philippines from which the species is known.

Lalage niger (Forster).

Fairly common.

Irena melanochlamys Sharpe.

This species was very abundant in Basilan and was more often killed in small trees near cultivated land than in forest. The figure which accompanies the original description[3] represents very poorly the coloration of lower parts. In the plate the line between black and blue of fore breast is altogether too sharpely defined and the blue is far too light.

Iole rufigularis (Sharpe).

This distinct species of fruit-thrush is abundant and does not differ in habits from its relative found in Luzon.

Poliolophus urostictus (Salvad.).

I am inclined to think that Steere's name *Poliolophus basilanicus* may have to be recognized for the bird inhabiting Basilan. The bill is noticeable longer and the white spots of rectrices occupy more space in Basilan specimens than in others from Luzon. The species is fairly abundant in the forest near Isabela.

Pycnonotus goiavier (Scop.).

Very abundant.

Ptilocichla basilanica Steere.

The length of tarsus (.11) given in the original description[4] is clearly a misprint for 1.11 inches.

Zosterornis capitalis (Tweed.).

Three specimens taken during February and March.

Macronus striaticeps Sharpe.

Abundant.

Copsychus mindanensis (Gm.).

One female, December 18.

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[3] *Trans. Linn. Soc.* Ser. 2 Zool. **1**, 334.

[4] Steere: List birds and mammals Steere Exp., Ann Arbor (1890), 18.

Locustella ochotensis (Midd.).

A male taken January 2. The species was abundant on flooded rice land and has not been recorded from Basilan.

Orthotomus mearnsi sp. nov.

Orthotomus frontalis SHARPE, Trans. Linn. Soc. 2d ser. Zool. (1877), **6**, 336–37 (pt.); TWEEDDALE, Proc. Zool. Soc. (1879), 72, MCGREGOR AND WORCESTER, Hand-List (1906), 88 (pt.).

Specific characters.—Similar to *Orthotomus frontalis* Sharpe but chestnut of forehead extending on crown to or nearly to posterior margin of eyes, not ending abruptly; the whole crown and nape slightly suffused with chestnut; behind eye the chestnut extends over side of nape; the crown never clear gray as in *O. frontalis.*

Type.—No. 6043, ♂, Bureau of Science Collection; Isabela, Basilan, P. I.; December 15, 1906; R. C. McGregor and A. Celestino.

Description of type.—Forehead, lores, and ring around eye chestnut, this color extending on crown to about opposite center of eye and then gradually fading, becoming merely a wash on occiput and neck; from behind eye the chestnut extends backward a little stronger than on back of head; rest of upper parts, including wings light olive-green; rectrices with light edges and wide, dusky tips; under parts white with more or less of the gray bases of feathers showing on throat and breast; flanks, pale greenish-yellow; thighs, chestnut. Total length in flesh, 4.5 inches; wing, 1.84; tail, 1.74; tarsus, 0.84.

Female.—The female does not differ from the male.

This species which is quite distinct, has been confused with *O. frontalis*, the error having originated with Sharpe who apparently had one male from Zamboanga, Mindanao, and two males from Basilan; the latter were supposed to be young birds. In the paper cited, Sharpe says: "The two young specimens seen to me to belong to the same species as the adult male: but this is by no means certain; for in one specimen I can detect a slight rufous shade on the sides of the crown, the adult *O. frontalis* of course not having this colouring."

Tweeddale also remarked the same difference and ascribed it to individual variation. He says: "The amount of rufous on the head of this species varies considerably in different individuals. In some it occupies the whole forehead and extends back to the vertex, and also colours the ear-coverts and a broad space below the eyes."

For comparison with Basilan birds I have had two examples collected by Mearns near Zamboanga and three collected by Clemens near Camp Keithley, Lake Lanao, Mindanao. The large series collected by us in Bohol are identical with specimens from Mindanao.

Orthotomus cinereiceps Sharpe.

Fairly abundant. Specimens occur with different amounts of white on chin and throat and I believe this is a sign of immaturity, the old birds having chin and throat pure black.

Acanthopneuste borealis (Blas.).

A male was taken December 24 and a female January 2. The occurrence of this species in Basilan appears to have been overlooked.

Artamus leucorhynchus (Linn.).

Fairly abundant.

Otomela lucionensis (Linn.).

A few examples seen.

Hyloterpe apoensis Mearns.

The thick-head of Basilan appears to belong to this species.

Callisitta lilacea (Whitehead).

This fine species is easily recognized as pointed out by Grant,[5] by the feathers of the face and ear-coverts being lilac instead of blue. The white loral spot is washed with lilac and there is a distinct nuchal band of the same color. A specimen of *C. œnochlamys* from Cebu has a heavier violet wash on lower parts than specimens from Bataan Province, Luzon.

Rhabdornis minor Grant.

A number of specimens secured.

Zosterops basilanica Steere.

The Basilan silver-eye was rarely observed and but few specimens were taken.

Dicæum papuense (Gm.).

Two males taken.

Dicæum hypoleucum Sharpe.

A number of specimens killed from flower trees.

Prionochilus olivaceus Tweed.

Specimens from Bohol and from Basilan seem to be specifically the same.

Eudrepanis pulcherrima (Sharpe).

A few specimens collected.

Cinnyris juliæ Tweed.

Abundant.

Cinnyris jugularis (Linn.).

Less abundant than the last.

Arachnothera flammifera Tweed.

Specimens from Bohol have bills considerably shorter than specimens from Basilan, but the coloration does not differ.

Anthreptes chlorigaster Sharpe.

A male was taken January 10.

Budytes leucostriatus Hom.

A male in winter plumage was taken January 2. The species is unrecorded from Basilan.

Anthus gustavi Swinh.

One specimen was killed on Malamaui.

Munia jagori Martens.

Very few seen.

Uroloncha everetti (Tweed.).

One female taken December 31.

Oriolus chinensis Linn.

Abundant.

Oriolus steerei Sharpe.

The small forest oriole of Basilan was very abundant near Isabela and a good series was collected.

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[5] Grant: *Ibis* (1906), 6, 474.

Dicrurus striatus Tweed.

This species was very abundant near Isabela. A female taken January 15 differs from the usual specimens in having feathers of lower breast and abdomen tipped with gray. A pensile nest of this species found March 12 is composed of plant fibers. Its inside diameter is 3 inches and its inside depth is 2 inches. The three eggs are light cream, almost white, in color decorated with faint spots of pale lilac and brighter spots of reddish brown, mostly near the larger end of the egg. The eggs measure: 1.14 by 0.76; 1.15 by 0.75; 1.16 by 0.77.

Sarcops melanonotus Grant.

Abundant.

Lamprocorax panayensis (Scop.).

Abundant.

Corone philippina (Bonap.).

Abundant.

DESCRIPTIONS OF FOUR NEW PHILIPPINE BIRDS.

By RICHARD C. McGREGOR.

Turnix celestinoi sp. nov.

Specific characters.—Similar to *Turnix whiteheadi* but larger, bill longer and heavier, wing and tarsus longer, coloration darker.

Type.—No. 5408, ♂, Bureau of Science Collection; Guindulman, Bohol Island, P. I.; collected June 22, 1906 by McGregor, Celestino and Canton.

Description of type.—Above, ground color black; feathers of head narrowly edged with dull-buff, paler on forehead; a narrow, median line of pale-buff from forehead to nape; hind neck, mantle, rump, and tail coverts with wavy broken cross lines of dark rusty-buff, obsolete on neck; lores and side of head, light-buff with small, black tips to feathers; a patch on each side of neck pale vinaceous-buff with narrow, black cross-lines; chin and throat, white, each feather with narrow buff tip; middle of abdomen, white; rest of lower parts rusty-buff, a trifle lighter than in *T. worcesteri;* sides of breast marked with a wide, black bar on each feather; primaries, secondaries, primary covers, and alula, slate; first primary and first feather of alula edged exteriorly with ocherous buff; secondary coverts and tertials with wide edges of ocherous-buff preceded by large, black spots or bars; wing lining and axillaries, slate; tail, bluish-slate and hidden by the long coverts. Total length, 5.0 inches; wing, 2.58; tail, 0.70; exposed culmen, 0.45; depth of bill at angle of gonys, 0.16; tarsus, 0.78; middle toe with claw, 0.74.

Zosterornis affinis sp. nov.

Zosterornis nigrocapitatus McGREGOR, Publications of the Bureau of Government Laboratories, Manila (1905), No. **34,** 29.

Specific characters.—Similar to *Zosterornis nigrocapitata* (Steere) but slightly larger; chestnut of chin and upper throat diffused and not forming a patch on each side.

Type.—No. 10260, ♂, Bureau of Science Collection; Lamao, Bataan Province, Island of Luzon, P. I.; collected December 3, 1904 by Celestino and Canton.

Description of type.—Forehead and crown, black, the shafts obscurely whitish; a small patch of chestnut behind each eye, next to the black crown; general color above dull olive-gray, feathers of neck and mantle with conspicuous, narrow, whitish shaft lines; rump, uniform; a narrow ring around eye, ear coverts, and cheeks gray with pale-yellow shaft lines; chin, throat, and fore breast, pale lemon-yellow the chin heavily washed with chestnut rufous which becomes gradually less on throat and disappears on breast; middle of breast and abdomen, very pale yellow, their sides gray, overlaid with a faint yellow wash; under tail coverts pale yellow; wings blackish-brown, outer edges of quills lighter and inner edges whitish; median and lesser coverts with light shaft lines; upper tail coverts dull olive-brown; rectrices, dark brown, except the outer feather, their outer webs edged with olive-brown, all but the center pair tipped with white, increasing in extent towards the outermost feather which has its outer web almost entirely white. "Length, 6.00 inches;" wing, 2.70; tail, 2.40; exposed culmen, 0.58; bill from front margin of nostril, 0.41; tarsus, 0.78.

The exact type locality of *Parus elegans* Lesson is unknown, but it is fair to assume that specimens from Luzon represent this species. Specimen No. 452 ♂, Bureau of Science Collection; Mariveles, Bataan Province, Luzon; February 18, 1902; McGregor and Celestino, is here used as a basis for comparison. It may briefly be described as follows:

Pardaliparus elegans (Lesson).

Head above, neck, cheecks, chin, throat, and fore breast glossy-black; space below eye, ear coverts, sides of neck, a large irregular spot on hind neck, breast, abdomen, under tail-coverts, and thighs lemon-yellow; flanks lightly washed with greenish-yellow; mantle with large spots of black, yellow, and white; lower back and rump olive-green; upper tail-coverts and rectrices black, the latter with white tips and two or three outer pair, with a white spot in middle of outer web; wings black; median and greater coverts and secondaries with large, white tips; small white spots on alula; outer webs of primaries narrowly edged with white or pale olive-green; quills edged with white on inner web; under wing coverts white, edged with yellow and mottled with blackish; irides and bill black; feet and nails plumbeous. Length in flesh, 4.75 inches; wing, 2.58; tail, 1.66: exposed culmen, 0.38; tarsus, 0.75.

Pardaliparus albescens sp. nov.

Parus elegans McGregor, Bull. Philippine Mus. (1903), **1**, 11 (Ticao and Masbate).

Pardaliparus elegans McGregor and Worcester, Publications of the Bureau of Government Laboratories (1906), **36**, 94 (part).

Specific characters.—Similar to *P. elegans* Lesson, but little or no olive-green on upper parts and the white much more extensive, to a large extent replacing the black.

Type.—No. 1000 ♂ adult, Bureau of Science Collection; Ticao Island, P. I.; May 9, 1902; R. C. McGregor and A. Celestino, collectors. Total length in flesh, 4.37 inches; wing, 2,53; tail, 1.55; exposed culmen, 0.38; tarsus, 0.72. Irides dark; bill black; legs and nails lead-color.

Remarks.—Gadow[1] observes that: "*Immature* birds and females have the back more yellow and olive-grey, the white spots and the white wash getting more pronounced in old birds, sometimes giving the back a nearly white appearance." While this is true, the characters assigned to the present species are believed to be quite independent of age and season. Adults from Masbate and Ticao agree in having these characters, while not one in a large series from Luzon shows them. It may be added that the wearing away of the tips of the dorsal feathers produces a considerable difference in the bird's appearance and in birds with worn plumage the yellow head band, the breast, and the abdomen become much paler in color than in freshly moulted birds. Excluding young birds, I have before me two skins from Ticao, three from Masbate, three from Mariveles, Luzon and 19 from Baguio, Benguet, Luzon. For a large part of the Benguet series I am indebted to Dr. E. A. Mearns.

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[1] Gadow: *Cat. Bds.* (1883), **8**, 23.

Pardaliparus edithæ sp. nov.

Pardaliparus elegans McGregor, Bull. Philippine Mus. (1904), **4**, 27.

Specific characters.—Size and color pattern as in *P. elegans* from which it is most easily distinguished by the reduction of the white spots on wing coverts and the general paler yellow, particularly of the light band on side of head and neck which is nearly pure white.

Type.—No. 3475, ♂, Bureau of Science Collection; Calayan Island, Babuyan Group, P. I.; collected October 5, 1903 by McGregor and Celestino.

Description of type.—Top of head, sides of neck, and mantle, glossy blue-black; an irregular white patch in center of nape; a number of large, white spots on mantle; back and rump gray washed with olivaceous; upper tail coverts glossy black; chin, throat and fore breast, dead black forming a large triangular patch, bounded above by a broad band of white, slightly washed with yellow, which extends under eye across ear coverts onto side of neck; rest of lower parts pale lemon-yellow washed with olivaceous on sides on neck and abdomen and on flanks; wings, glossy black; primaries, narrowly edged with gray on their outer webs and with white on the inner; greater and median coverts with white spots at tips (much smaller than in *P. elegans* and not forming bands as in that species); secondaries tipped with white; tail, black with white markings as in *P. elegans*, but the white tips much smaller than in the latter species. Bill, black except basal third which is whitish; legs dull-blue; nails horn-brown. Total length, 4.8 inches; wing, 2.66; tail, 1.70; culmen from base, 0.48; bill from nostril, 0.39; tarsus, 0.72; middle toe with claw, 0.68.

Pardaliparus mindanensis (Mearns).

Pardaliparus elegans mindanensis Mearns, Proc. Biol. Soc. Wash. (1905), **18**, 8 (Mindanao).

This species is the smallest among the Philippine members of its genus; it may be recognized by its small bill and the dark and yellow coloration of upper parts.

THE OCCURRENCE OF BLYTH'S WATTLED LAPWING AND THE SCAUP DUCK IN THE PHILIPPINE ISLANDS.

By Richard C. McGregor.

Through the interest of Dr. Leon Guerrero, a Filipino naturalist residing in Manila, the Bureau of Science has aquired a perfect specimen of Blyth's wattled lapwing, *Microsarcops cinereus* (Blyth),[1] which represents a subfamily of birds not previously known to occur in these Islands. Sharpe gives the range of this species as "From Corea and the southern Japanese islands to Mongolia and northern China, wintering in southern China, the Indo-Burmese countries, and northeastern Bengal." The species may prove to be a regular winter visitant to the Philippines.

The present specimen, a male in young winter plumage, was taken January 20, 1906, near Malabon, a short distance from Manila. The specimen is about 12.3 inches in length; wing, 9; tail, 4; tarsus, 2.9; culmen, 1.5. This bird resembles a large plover, but is distinguished by having a small hind toe, a short and blunt wing spur, and a small, fleshy wattle or lappet between the eye and base of bill. The plumage may be described as follows:

Upper parts, brown with a slight gloss, the feathers with dusky shafts; forehead and neck a trifle lighter and grayer; upper tail coverts and tail, white, rectrices with a subterminal blackish band which is widest on central pair and absent from outermost pair; chin whitish; throat and sides of head and neck, light brown with whitish streaks; breast brown, rest of under parts, white; wing coverts, brown like the back but a little paler, median coverts with narrow, white tips, except the outer ones which are pure white; greater coverts, nearly entirely white, with brown at extreme base, increasing in extent on inner ones; alula dark brown; primary-coverts and quills, black; secondaries, white, the inner one externally light brown and the innermost brown like the black. "'Basal two-thirds of bill deep yellow, the terminal third black; feet dull yellow, claws black; edges of eyelids and lappets deep yellow' (*E. W. Oates*)."

Through the courtesy of Mr. W. Parsons, of Manila, I am permitted to record the capture of a male scaup duck, *Fuligula marila* (Linn.),[2] at Tanay, Laguna de Bay, Luzon, in November, 1906. This species is unrecorded from the Philippines, although found as a winter visitant in China and Japan; it has also been recorded from the Liu Kiu Islands.[3]

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[1] Sharpe: *Cat. Bds.* (1896), **24**, 133.

[2] Salvadori: *Cat. Bds.* (1895), **27**, 355.

[3] Stejneger: *Proc. U. S. Nat. Mus.*, Wash. (1887), **10**, 415.

NOTE ON A BIRD UNRECORDED FROM MINDANAO.

By Richard C. McGregor.

Rhabdornis inornata Grant.

Rhabdornis inornatus Grant, Bull. Brit. Ornith. Club (1896), **6**, 18; Ibis (1897), **3**, 235 pl. 6, fig. 2.

This species has been met with in Samar only, where Whitehead took three males, the female to the present time remaining unknown. In a collection recently received from Chaplain Joseph Clemens, United States Army, is a female bird evidently of this species. It agrees quite closely with the colored plate of the male but differs in having top of head dull-brown instead of dark-gray. This specimen was taken near Camp Keithley, Lake Lanao, Mindanao, on May 3, 1907, and yields the following measurements: Wing, 3.50 inches; tail, 2.26; exposed culmen, 0.64; tarsus, 0.80; middle toe with claw, 0.89.

NOTES ON SPECIMENS OF THE MONKEY-EATING EAGLE (PITHECOPHAGA JEFFERYI GRANT) FROM MINDANAO AND LUZON.

By RICHARD C. McGREGOR.

Through the courtesy of Chaplain Joseph Clemens and Lieutenant Farrel of the Fifteenth Infantry, United States Army, I have been able to examine a specimen of *Pithecophaga jefferyi*, taken near Camp Keithley, Lake Lanao, Mindanao. The specimen was purchased from a Moro by Lieutenant Farrel and was sent by him to the Bureau of Science. Unfortunately, several of the primaries on each wing have been clipped and the cere has apparently been eaten by ants, but otherwise the specimen is in good condition. Its sex was not determined. Compared with the one in the Bureau of Science collection, which was taken in Luzon, the present specimen is found to differ in being slightly larger and the feathers of the chin, the side of the jaw, and of the malar region have distinct, blackish shaft stripes.

The following measurements may be added: Wing (primaries clipped), 23.75 inches; tail, 18.25; chord of culmen without cere, about 2.35; depth of upper mandible at nostril, 1.54; width of upper mandible where cere meets tomium, 0.84; tarsus, 5; middle toe with claw, 4.60; hind toe with claw, 3.54; width of middle tail feather, 3.30.

Later, a second more perfect specimen was received from Chaplain Clemens. This specimen, a male, was taken near Camp Keithley, September 27, 1906, and yields the following measurements: Wing, 24.80; tail, 18.75; chord of culmen without cere, 2.57; depth of upper mandible at nostril, 1.66; width of upper mandible where cere meets tomium, 0.80; tarsus, 4.63; middle toe with claw, 3.78; hind toe with claw, 3.22; width of middle tail feather, 3.30.

On May 11, 1907, Mr. H. M. Ickis, geologist in the Bureau of Science, killed a specimen of the monkey-eating eagle on the Agus River, in eastern Rizal Province, Island of Luzon. This is, I believe, the first specimen positively known to have been taken in Luzon. The head, a wing, and a foot were brought to Manila. In this specimen the feathers of the chin and the side of the face have the black shaft stripes noted in the specimens from Mindanao. Measurements were taken from the fragments as follows: Wing, 23.25; chord of culmen without cere, 2.45; depth of upper mandible at nostril, 1.57; width of upper mandible where cere meets tomium, 0.73; tarsus, 4.5; middle toe with claw, 3.83; hind toe with claw, 3.25.

NOTES ON BIRDS COLLECTED IN CEBU.

By Richard C. McGregor.

INTRODUCTION.

Cebu Island is of very peculiar ornithological interest, this interest is so great not only because of the species lacking in its fauna but also because of those limited in their range to its territory.

Zoölogically, Cebu is the most anomalous island of the Philippine Archipelago. The greater part of its west coast is nearly parallel with the east coast of Negros; while the southern point of Cebu is within 4 miles of the Negros coast, yet the species of birds known from the two islands are very different.

Not far distant and southeast of Cebu is the island of Bohol[1] but the birds of Cebu and Bohol show scarcely any relationship; in fact these two islands are less closely related than are Luzon and Basilan.

Worcester[2] has fully discussed the fauna of Cebu and has shown that while it contains some elements strongly suggestive of a close relationship to that of the central Philippines,[3] the island in reality must be separated from that group.

The positive evidence of the necessity for separating Cebu from the central Philippines consists in the presence of the following species which are peculiar to Cebu:

SPECIES PECULIAR TO CEBU.

Phapitreron frontalis.
Loriculus chrysonotus.
Oriolus assimilis.
Dicæum pallidior.
Prionochilus quadricolor.
Cryptolopha cebuensis.
Chloropsis flavipennis.[4]
Cittocincla cebuensis.
Iole monticola.
Edoliisoma cebuensis.
Artamides cebuensis.

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[1] The town, of Cebu and Point Corte, the nearest point in Bohol, are less than 20 miles apart, with Mactan, Olango, and other smaller islands between them. Further south Argao in Cebu is but 14 miles from the Bohol coast.

[2] *Proc. U. S. Nat. Mus.*, Wash. (1897), **20**, 579–580. For an account of the topography and geology of Cebu see Smith: *This Journal* (1906), 1, 1043.

[3] The Central Philippines comprise the islands of Negros, Panay, Guimaras, Bantayan, Masbate, and Ticao.

[4] Erroneously recorded from Mindanao. See Worcester: *Publications of the Bureau of Government Laboratories*, Manila (1906), No. **36**, 78 (footnote).

On the other hand we find that the genera *Chrysocolaptes* and *Orthotomus* and the families *Bucerotidæ* and *Timeliidæ*, all conspicuously represented in Negros, are entirely wanting in Cebu. Worcester[5] says:

> It seems to me evident from the large number of important forms in the central Philippines which do not occur in Cebu, and from those in Cebu which are wanting in the central Philippines, that the avifaunæ of the two islands were originally very distinct. The wonder is not that eight species[6] should have made their way in one direction or the other over 4 miles of sea, but rather that 34 species should have failed to cross or, having crossed, should have failed to establish themselves.

The collections which form the basis of the present paper were made by the author and assistants at Danao, July 24 to August 3, 1906; at Toledo, September 21 to November 14, 1906; and at Minglanilla, November 15 to 26, 1906.

Danao is on the east coast some 20 miles north of the town of Cebu. Collecting at Danao was almost useless and but two important species, *Accipiter manillensis* and *Tachornis pallidior*, were secured.

Toledo, on the west coast, was reached from the Island of Bantayan. It was at this point that Worcester and Bourns did their most important work in the island. We found that a large part of what was level forest land sixteen years ago is now sugar-cane field. The larger trees have been cut and the little forest remaining along streams and on steep hillsides is rapidly disappearing.

Minglanilla is on the coast a short distance south of Cebu. Collections of water birds only were made at this point.

Of the 114 species collected or fully identified by us, 24 appear to be unrecorded from Cebu, making a total of 149 bird species now known from Cebu.

SPECIES NOT PREVIOUSLY RECORDED FROM CEBU.

Amaurornis phœnicura.
Arenaria interpres.
Squatarola helvetica.
Ochthodromus geoffroyi.
Ochthodromus mongolus.
Ægialitis peroni.
Ægialitis alexandrina.
Numenius cyanopus.
Terekia cineria.
Ancylochilus subarquatus.
Glottis nebularius.
Limicola platyrhyncha.
Egretta garzetta.
Accipiter gularis.
Accipiter manillensis.
Haliaëtus leucogaster.
Caprimulgus griseatus.
Caprimulgus manillensis.
Salangana whiteheadi.
Tachornis pallidior.
Hirundo gutturalis.
Hirundo striolata.
Budytes leucostriatus.
Anthus gustavi.

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[5] *Proc. U. S. Nat. Mus.*, Wash. (1897), **20**, 590.

[6] These eight species are: *Phapitreron nigrorum, Alcyone nigrirostris, Xantholæma roseum, Yungipicus maculatus, Dicrurus mirabilis, Æthopyga bonita, Æthopyga magnifica, Hyloterpe winchelli.*

NOTES ON THE SPECIES OBSERVED.

Gallus gallus (Linn.).

The jungle fowl is rare in Cebu; it was seen in the vicinity of Toledo where a few indivduals were killed and a very young chick was caught in November.

Osmotreron axillaris (Bp.).

Rare; only one obtained.

Osmotreron vernans (Linn.).

Rare; only one killed.

Phapitreron nigrorum Sharpe.

Rare; one specimen from forest near Toledo.

Leucotreron occipitalis Bp.

An adult male from vicinity of Toledo.

Muscadivora ænea (Linn.).

Feeding in very tall trees near Toledo, making its capture next to impossible. One or two examples killed.

Streptopelia dussumieri (Temm.).

Not common; a female killed November 25 had a hard shelled egg in the oviduct.

Chalcophaps indica (Linn.).

One day while I was stationed near a fig-tree waiting for *Dicœidæ*, an Indian bronze-winged dove lit on the ground within three feet of me, then discovering me it flew off in great haste. This species does not seem to be common in Cebu.

Hypotænidia torquata (Linn.).

One specimen from Toledo.

Amaurornis olivacea (Meyen).

An adult of this species was snared by a native boy and on October 25 the same boy caught a downy young bird probably of the same kind. The legs appeared very large and long in proportion to the size of its body. The bill was black, with the tip whitish; irides and legs dark-brown; entire plumage coal-black; nail on wing prominent. No specimen was obtained by us.

Amaurornis phœnicura (Forster).

A specimen was taken at Danao but the species was not observed elsewhere in the island.

Sterna boreotis (Bangs).

Not uncommon off shore near Toledo where it was feeding among schools of minute fish. One example killed from the beach on November 12.

Arenaria interpres (Linn.).

The turnstone was obtained at Toledo in September and at Minglanilla in November.

Squatarola helvetica (Linn.).

Three specimens in winter plumage taken at Minglanilla, November 16 to 23.

Charadrius fulvus (Gm.).

The Eastern golden plover was found in small numbers at Minglanilla. Two from Toledo, September 28, retain many black feathers on breast and abdomen.

Ochthodromus geoffroyi (Wagl.).

Very common at Minglanilla in November; one taken at Toledo, September 28.

Ochthodromus mongolus (Pall.).
Abundant at Minglanilla in November.

Ægialitis dubia (Scop.).
One from Minglanilla, November 23, and a bird in adult plumage from Toledo, October 24.

Ægialitis peroni (Bp.).
One from Toledo, September 29.

Ægialitis alexandrina (Linn.).
Abundant at Toledo and Minglanilla.

Numenius cyanopus Vieill.
A female of this large curlew was taken at Toledo, November 11 and a male at Minglanilla, November 19.

Numenius variegatus (Scop.).
This smaller curlew was not uncommon near Toledo and a specimen was taken at Minglanilla, November 20. A female was taken at Danao, August 1.

Terekia cinerea (Güldenst.).
This curious sandpiper was met with in considerable numbers on the tide flats near Minglanilla in November. At or near high water the species was found, in company with *Heteractitis*, resting among the roots of mangrove trees and at such a time it was no uncommon occurrence to kill several specimens of each species at one shot. As the rocky flats became exposed these birds scattered to feed and became more difficult to approach. The bill of the female is much longer than that of the male, but the plumage is similar in the two sexes. In a male taken November 20, the bill was black, except the yellow base, legs bright orange-chrome, and nails black. Specimens from Minglanilla agree perfectly with the description given by Oates.[7] Instead of the vernacular names "curlew sadpiper" and "pigmy curlew" quoted by Oates as being applied to this species, godwit sandpiper would seem more appropriate as the bill of *Terekia* curves upward just as with the godwits.

Ancylochilus subarquatus (Güldenst.).
The only specimen of this stint obtained is a male which was killed from among a flock of *Limonites* at Minglanilla, November 17.

Totanus eurhinus (Oberh.).
A male and female of the redshank from Minglanilla in November.

Heteractitis brevipes (V.).
This tatler was very abundant near Minglanilla and specimens are mostly in winter plumage, yet a few show traces of cross bars remaining from the summer dress.

Actitis hypoleucus (Linn.).
One from Minglanilla.

Rhyacophilus glareola (Gm.).
Noted at Danao.

Glottis nebularius (Gunn.).
Several specimens in winter plumage from Minglanilla. In a male taken November 20 the bill was plumbeous, darker at tip; legs, drab, more bluish at joints and more yellowish on the tarsi; claws, black.

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[7] Birds Brit. Burmah (1883), 2, 407.

Limonites ruficollis (Pall.).

Very abundant on tide flats at Minglanilla where a number were taken. September 20 in the channel between Cebu and Negros I observed 40 to 50 small sandpipers which were probably of this species. They were in flocks of from three to eight and apparently migrating southward. Small parties often lit near our boat, rested a few moments and continued their flight.

Limicola platyrhyncha (Temm.).

A male from Minglanilla, November 23, is in fresh winter plumage; bill and legs black. This sandpiper has not been previously recorded from Cebu.

Egretta garzetta (Linn.).

A male from Minglanilla, November 17. Legs, black, feet and lower part of tarsi, greenish-yellow; bill, black, base of lower mandible, white; irides, yellow; bare skin around eyes pale-yellow.

A female from Minglanilla, November 28. Irides, pale straw-yellow; bill, yellow, mottled with brown; legs, green with patch of black on lower tarsi; skin around eyes, pale green.

Nycticorax manillensis Vig.

A specimen of the Manila night heron was taken on the river near Toledo.

Butorides amurensis (Schrenck).

If this variety is entitled to recognition on the characters of larger size and coarser and stronger bill, then a specimen taken by us at Toledo, October 29, must be labelled with the above name.

Bubulcus coromandus (Bodd.).

A large flock of this common species seen in a mangrove swamp near Minglanilla where one specimen was taken.

Accipiter gularis (Temm. & Schl.).

A female hawk taken at Toledo, October 27, does not differ from specimens from Calayan which I refer to *A. gularis*. Length, 11.6 inches; wing, 7.80; tail, 5.80; tarsus, 1.66. Irides, cere, and legs yellow; bill and nails black. Stomach contained bits of a large green locust.

Accipiter manillensis (Meyen).

A female of this species taken near Danao, July 28, had a nest of small sticks on a horizontal branch of a tall tree. The determined efforts of the parent bird to drive me from the neighborhood indicated that the nest was in use. It was impossible to reach the nest without ropes and other tackle. Total length of fresh specimen, 12.3 inches; wing, 7.10; tail, 5.30; tarsus, 2.12. Bill horn blue; cere waxy green; irides and eyelids chrome yellow; legs greenish yellow; nails blackish.

Butastur indicus (Gm.).

Occasionally seen and heard near Toledo; one killed was very fat.

Haliaëtus leucogaster (Gm.).

A captive of this species was seen in the town of Cebu; individuals were also seen at Toledo.

Haliastur intermedius Gurney.

This species is abundant. On November 6 a pair were observed at work on a nest in a tall tree near the river.

Ninox japonica (Temm. & Schl.).

A specimen was taken.

Ninox spilonota Bourns & Worcester.

A male owl from Oro in the mountains back of Toledo appears at first sight to represent a species very distinct from *N. spilonota,* as much of the plumage is white, this being most conspicuous on scapulars, chin, throat, and under tail coverts. In dimensions, however, this specimen does not differ greatly from a male taken in Sibuyan and I believe that the Cebu skin is merely an extremely light example of the above species.

Cacatua hæmaturopygia (P. L. S. Müll.).

Not very abundant; noted at Danao and Toledo.

Prioniturus discurus (Vieill.).

Fairly common near Toledo.

Tanygnathus lucionensis (Linn.).

Rare.

Loriculus chrysonotus Scl.

While at Toledo we spent considerable time hunting in coconut groves near the beach without finding a single lorikeet, but we found several birds of this species feeding at a few coconut trees near the forest and killed a few solitary birds in the forest. We failed altogether to get adults. The following notes respecting this species are from a manuscript by Worcester and Bourns.

"The only *Loriculus* which we failed to find abundantly in coconut trees where the trees themselves were accessible. In 1888 several days of hard work in the great coconut groves near Carmen, Cebu, brought us but a single specimen. In 1893, however, we found it quite abundant in the woods near Toledo. It is possible that its disappearance from the coconut groves of the east coast is due to the lack of suitable breeding ground near by. The forest has been almost entirely cleared from the Island and the little which remains will soon be gone."

Eurystomus orientalis (Linn.).

The oriental roller was seen at Danao.

Pelargopsis gigantea Walden.

One killed and another individual seen on the river near Toledo.

Alcedo bengalensis Briss.

Obtained along the river near Toledo and on the beach at Minglanilla. *Alcyone* was not once seen.

Ceyx bournsi Steere.

One specimen obtained near Toledo.

Halcyon gularis (Kuhl).

Seen at Danao.

Halcyon chloris (Bodd.).

Collected at Toledo.

Merops americanus P. L. S. Müller.

One specimen of the bay-headed bee-bird from Toledo.

Merops philippinus Linn.

A male from Danao July 25.

Caprimulgus griseatus Wald.

Abundant on the beach near Toledo.

Caprimulgus manillensis Wald.

Less abundant than *C. griseatus* but found in the same place on the beach. A specimen was killed over a grassy field near mangrove swamp.

Salangana whiteheadi (Grant).

A male from Danao, July 27, must be referred to this species as the tail is forked and the tarsi are devoid of plumes.

Salangana troglodytes Gray.

Abundant in the forest near Toledo. One specimen preserved is slightly albinistic.

Salangana marginata Salvad.

A male from Danao, July 26. A nesting colony was found near Toledo. The nests were composed of sandy mud and were plastered against the face of perpendicular cliffs in a narrow gorge. A few birds were building in a small rocky cave. At the time of my visit to the colony there were some twenty nests in process of construction and none contained eggs so far as could be determined.

Tachornis pallidior McGregor.

At Danao the paler palm swift was observed in small numbers over or near the town and a small series was collected. This species was also observed feeding over sugar cane fields near Toledo. The palm swift was never detected near forest where flocks of *Salangana marginata* and *S. linchi* were seen almost daily.

Cacomantis merulinus (Scop.).

One from Danao.

Centropus viridis (Scop.).

Noted at Danao and Toledo.

Xantholæma roseum (Dumont).

A female from Toledo where the species was not uncommon; a male was taken at Danao, July 26.

Yungipicus maculatus (Scop.).

Three specimens from Toledo.

Thriponax javensis (Horsf.).

Taken near Toledo.

Pitta atricapilla Less.

Taken at Danao.

Hirundo gutturalis Scop.

Abundant in the vicinity of Toledo.

Hirundo javanica Sparrm.

One specimen from Toledo.

Hirundo striolata Boie.

Specimens of the mosque swallow were secured at Toledo on September 28 and againt on November 12. The specimens are in freshly moulted plumage and do not differ in any detail from specimens of this type collected in Calayan Island.[8] It is possible that the mosque swallow inhabiting the Philippine Islands may take rank as a geographical race as yet unnamed, but it is impossible for me to characterize such a race wihout typical specimens of *striolata*, *japonica*, etc.

Cyornis philippinensis Sharpe.

Not uncommon; one from Danao and two from Toledo.

Hypothymis occipitalis (Vig.).

Fairly abundant.

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[8] McGregor: *Bull. Phil. Mus.* (1904), No. 4, 33.

Rhipidura nigritorquis Vig.

This common fan-tailed flycatcher was abundant.

Zeocephus rufus (Gray).

One specimen from Toledo, October 19.

Cryptolopha cebuensis Dubois.

This distinct species is not uncommon in the wooded portions of Cebu. A female secured does not materially differ in plumage from the male which was carefully described in the original diagnosis.[9] Irides dark gray; upper mandible black, lower mandible pale yellow; legs and feet light plumbeous.

Measurements of Cryptolopha cebuensis.

Locality.	Sex.	Wing.	Tail.	Exposed culmen.	Tarsus.
Toledo, Cebu	♂	2.30	1.80	0.44	0.72
Do	♂	2.24	1.93	.43	.76
Do	♂	2.30	1.94	.46	.77
Do	♂	2.30	1.80	.46	.76
Do	♂	2.25	1.86	.44	.72

Artamides cebuensis Grant.

Grant[10] characterizes the adult male as "Very nearly allied to the male of *A. mindorensis* Steere, from which it only differs in being larger and in having the feathers covering the nostrils gray instead of deep black." In specimens before me these characters are well defined and it may be added that in *A. mindorensis* the entire lores, the chin, and a patch at base of maxillary ramus are jet black, while in *A. cebuensis* the lores are blackish and the jaw is slate gray uniform with the chin and throat.

Measurements of Artamides mindorensis and A. cebuensis.

Species.	Sex.	Wing.	Bill from nostril.
A. mindorensis.	♂	6.32	0.80
Do	♂	6.50	.83
Do	♂	6.38	.84
A. cebuensis	♂	6.72	.92
Do	♂	6.58	.93
Do	♂	6.78	.94

Edoliisoma alterum Wardlaw-Ramsay.

Fairly common in forest along streams. Usually observed at considerable height from the ground and easily detected by its pleasing whistle. A male and female were commonly seen in company and occasionally two pairs were seen in one tree.

This species is separable from the Luzon birds (*E. cærulescens*) as pointed out in the original description,[11] by having the plumage of the male glossed with green, while in *cærulescens* it is glossed with blue. The female of *alterum* is of a lighter gray than the female of *cærulescens*. In *alterum* the three outer rectrices may be narrowly tipped with white, but apparently this is not a constant character and is due perhaps to extreme maturity. Irides, dark brown; bill, legs, and claws, black.

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[9] *Cryptolopha flavigularis* Bourns & Worcester, *Occ. Papers Minn. Acad.* (1894), **1**, 23.

[10] *Ibis* (1896), **2**, 535.

[11] *Ibis* (1881), **5**, 34.

Measurements of Edoliisoma cærulescens and E. alterum.

Species.	Sex.	Locality.	Wing.	Tail.	Bill from nostril.	Depth at angle of gonys.
E. cærulescens	♂	Mariveles, Luzon	5.35	5.00	0.80	0.32
Do	♂	do	5.12	4.60	.74	.32
Do	♂	do	5.18	4.72	.76	.33
Do	♂	do	5.00	4.30	.70	.32
E. alterum	♂	Toledo, Cebu	4.95	4.34	.73	.30
Do	♂	do	5.08	4.54	.72	.32
Do	♂	do	5.35	4.57	.74	.34
Do	♂	do	5.10	4.72	.74	.32

Lalage niger (Forster).

One specimen from Danao.

Chloropsis flavipennis (Tweedd.).

This species was observed in the leafy tops of trees near streams and was very rare, only six specimens being obtained.

Measurements of Chloropsis flavipennis.

Locality.	Sex.	Wing.	Tail.	Bill from nostril.
Toledo, Cebu.	♂	3.74	2.96	0.66
Do	♂	3.80	3.00	.67
Do	♂	3.60	2.90	.62
Do	♀	3.60	3.00	.63
Do	♀	3.58	2.88	.59
Do	♀	3.50	2.84	.60

Iole philippensis (Gm.).

Fairly abundant in the vicinity of Toledo.

Iole monticola Bourns & Worcester.

This large and very distinct species was extremely rare and was found only in forest near Toledo.

Measurements of Iole monticola.

Locality.	Sex.	Wing.	Tail.	Exposed culmen.
Toledo, Cebu	♂	4.78	4.26	0.97
Do	♂	4.58	4.40	.96
Do	♂	4.80	4.40	.98

Pycnonotus goiavier (Scop.).

One specimen from Danao.

Copsychus mindanensis (Gm.).

Noted at Danao.

Cittocincla cebuensis Steere.

An immature male from Toledo, October 13, differs from the adult as follows: feathers of crown and nape tipped with dull rusty-brown; wings, dull seal-brown; each feather of alula and greater coverts with a subterminal spot of ocherous-brown; lesser coverts, black fringed with silvery-gray; lower parts, dull blue-gray, tips of feathers ocherous becoming more rusty on flanks.

Two adult males measure as follows: wing, 3.55, 3.75; tail, 4.16, 3.90 (imperfect); exposed culmen, 0.60; tarsus, 1.08, 1.00.

Pratincola caprata (Linn.).

Seen at Danao only.

Acrocephalus orientalis (Temm. & Schl.).

A female was taken at Toledo, November 13, and another the next day.

Cisticola exilis (Vig. & Horsf.).

One specimen from Danao; common.

Megalurus ruficeps Tweedd.

Fairly abundant near Toledo.

Acanthopneuste borealis (Blas.).

The northern willow warbler was not abundant in Cebu, but two specimens being taken, October 15 and 19 respectively.

Artamus leucorhynchus (Linn.).

Noted at Danao and Toledo.

Cephalophoneus nasutus (Scop.).

A male in fresh plumage from Toledo, October 30.

Otomela lucionensis (Linn.).

A male with pale-gray forehead is typical of the species; another specimen, female, October 18, has the entire upper parts dark, slightly reddish-brown, obsoletely cross-barred; sides of throat and breast, flanks, and thighs with dusky, V-shaped bars, strongly suggestive of immaturity.

Hyloterpe winchelli Bourns & Worcester.

Three specimens of Winchell's thick-head were obtained near Toledo.

Pardaliparus elegans (Less.).

At Danao an adult male of this titmouse was taken July 30. Near Toledo another adult male was taken, October 24, and two young birds were collected, September 26 and October 24, respectively.

Callisitta œnochlamys (Sharpe).

A male from Toledo, October 19.

Zosterops everetti Tweeddale.

A pair from Danao, July 30.

Dicæum papuense (Gmel.).

Abundant and usually found feeding at the fruit of wild fig trees (*Ficus* sp.)

Dicæum pallidior Bourns & Worcester.

This species is the most common member of the family *Dicœidœ* in Cebu. It is closely related to *Dicœum dorsale* but appears to deserve recognition. It is quite probable that the name *Dicaœum flaviventer* refers to the same species but from lack of literature I am unable to determine which name has priority.

Dicæum pygmæum (Kittlitz).

An adult male from Toledo, October 18.

Prionochilus quadricolor Tweedd.

This handsome species is rare and strictly confined to the forest. Of over 50 specimens of *Dicæidæ* collected by us in Cebu only five are of this species. An adult male agrees with the original description [12] but the head and neck are black, slightly glossed with blue, not "dull black." The plate is faulty in showing too much yellow on the rump and not enough red on the interscapulars; the latter are clear red with no mixture of yellow. A young male taken October 15, has the lower parts like the adult but upper parts and tips of tertiaries and greater coverts dull olive-green.

Æthopyga magnifica Sharpe.

This large and beautiful sun bird was fairly abundant in small bushes along forest streams. Its song, though not elaborate is very sweet and pleasing. Specimens from Cebu do not differ in any respect from examples collected in Sibuyan.

Æthopyga bonita Bourns & Worcester.

A male and a female from near Toledo.

Cinnyris jugularis (Linn.).

One specimen taken at Danao.

Anthreptes chlorigaster Sharpe.

Only a male and a female obtained.

Motacilla melanope Pall.

This wagtail was seen daily in the vicinity of Toledo.

Budytes leucostriatus Hom.

A pair in plan winter plumage taken on the beach near Toledo, September 29.

Anthus gustavi Swinh.

One specimen from near Toledo, October 29.

Passer montanus (Linn.).

This introduced sparrow has become well established in the town of Cebu and was observed at Danao. It was not observed on the west coast.

Munia jagori Martens.

Jagor's rice-bird was found breeding in numbers near Toledo and several nests containing fresh eggs were taken from screw pines (*Pandanus*) on September 28.

Oriolus chinensis Linn.

One of the more common species in Cebu.

Oriolus assimilis Tweedd.

This forest oriole was not uncommon near Toledo. While it is plainly of the *Oriolus steerei* type it differs in being larger, in the much darker and greener upper parts and under tail-coverts, in the darker throat and breast, in the wider black markings of abdomen, and in the reduced yellow tips of rectrices.

Adult male, October 13. Irides, bright red; bill, dull red-brown; feet, lead-blue; nails, black. Immature male, October 13. Irides white; bill brown; legs lead blue; nails black.

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[12] Tweeddale; *Proc. Zool. Soc.* (1877), 762.

Measurements of Oriolus assimilis.

Locality.	Sex.	Wing.	Tail.	Exposed culmen.
Toledo, Cebu	♂	4.80	3.58	0.85
Do	♂	4.90	3.60	.88
Do	♀	4.60	3.38	.86
Do	♀	4.58	3.35	.85

Dicrurus mirabilis Walden & Layard.

A few specimens were taken near Toledo.

Sarcops calvus (Linn.).

A female from Toledo, November 3, has the back rather dark and should perhaps be referred to *S. melanonotus*.

Lamprocorax panayensis (Scop.).

Abundant at Danao and Toledo.

Corone philippina (Bonap.).

Abundant.

BIRDS OBSERVED IN BANTAYAN ISLAND, PROVINCE OF CEBU.

By RICHARD C. McGREGOR.

Bantayan is an island 47 square miles[1] in area, lying 8 miles west of the northern portion of Cebu Island and northeast of the northeastern point of Negros. The 22 miles between Bantayan and Negros is partially bridged by the Dons, a series of seven isles varying from 0.1 to 1.3 square miles in area, and very shallow water is found for a considerable distance from Bantayan toward Negros.

The surface of Bantayan is flat, the soil sandy and rather poor, and the native vegetation offers but little attraction. There are no streams and but one or two small, shallow ponds. A large area of tide flats is exposed at low water, affording feeding ground for many migratory shore birds.

Corn is the staple food product, and among fiber plants the pineapple and maguey are planted in quantities affording a steady source of revenue to the inhabitants of the island. The women are industrious and expert workers on the loom.

Groves of coconut trees extending in an almost unbroken band along the shore afford excellent feeding ground for *Loriculus*, but neither search nor inquiry resulted in any evidence of its presence.

Birds were collected on Bantayan from August 20 to September 21, 1906, and 66 species were recorded. Of these *Orthotomus cinereiceps* and *Iole guimarasensis* demonstrate that this island belongs with the central Philippines (Panay, Negros, Guimaras, Masbate, Ticao) and not with Cebu. *Dicrurus mirabilis,* while a central Philippine species, is found also in Cebu; its presence in Bantayan, therefore, merely unites the fauna of that island with the central group without separating it from Cebu.

LIST OF SPECIES.

Megapodius cumingi Dillw.

No individual of this species was seen but I feel justified in recording it from the island on the strength of the examination of two large mounds which were evidently in use by birds on September 3, 1906.

Osmoteron vernans (Linn.).

Two males and a female.

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[1] Areas of islands from *Census of the Philippine Islands* (1903), 1, 270.

Leucotreron leclancheri (Bp.).

This dove was rare; one specimen was taken August 23, 1906.

Muscadivora ænea (Linn.).

Uncommon; two specimens.

Myristicivora bicolor (Scop.).

A young bird of this species was taken from its nest on August 24, 1906, and two adult males were killed the same day; very few individuals were seen.

Streptopelia dussumieri (Temm.).

Abundant.

Hypotænidia torquata (Linn.).

One specimen taken.

Gallicrex cinerea (Lath.).

This species is not represented in the collection but was identified in the field beyond any reasonable doubt.

Sterna boreotis (Bangs).

Terns were not uncommon about a sandy beach near Santa Fé and one example was preserved.

Arenaria interpres (Linn.).

Turnstones were abundant, usually keeping in small flocks distinct from other shore birds. Two specimens taken August 27, 1906, still retain much of the summer plumage.

Squatarola helvetica (Linn.).

Rare; one specimen September 5, 1906.

Charadrius fulvus (Gm.).

Two specimens of the Eastern golden plover, August 23, 1906, and September 5, 1906, are in mixed plumage, the black of lower parts, however, still predominating over the white.

Ochthodromus geoffroyi (Wagl.).

Ochthodromus mongolus (Pall.).

The two above species were very abundant on tide flats at low water.

Ægialitis peroni (Bp.).

Usually found singly or in pairs along sandy beaches and much rarer than the two species of *Ochthodromus.*

Numenius variegatus (Scop.).

Curlews were very abundant in large flocks on tide flats near the town of Bantayan. Six specimens preserved are of this species and another much larger species was seen.

Limosa novæ-zealandiæ Gray.

This godwit was abundant on tide flats and specimens were obtained without difficulty, a number often being killed at one shot. Skins preserved, August 20 to September 14, 1906, represent both summer and winter plumages. The natives of Bantayan call this species "ma-ni-ug-suc."

Totanus eurhinus (Oberh.).

A female was taken August 24. Iris brown; bill black except basal half of under mandible which is light orange; legs and feet light reddish orange; claws blackish.

Heteractitis brevipes (Vieill.).

Many specimens taken with remnants of the mottled summer plumage, others in plain winter dress. Known to natives of the island as "ta-ling-ting" but the name is not always restricted to this species.

Actitis hypoleucus (Linn.).

One specimen.

Limonites ruficollis (Pall.).

A good series of this stint. A female of August 27, 1906, still retains much of the pretty summer plumage but the other specimens show little traces of it. Known in Bantayan as "ti-ut'-ti-ut'."

Gallinago megala Swinh.

Snipe are rare in Bantayan as there is little ground suited to their needs. A female was taken September 17, 1906, and a few more were seen.

Ardea sumatrana Raffl.

Each day a number of large herons were feeding in shallow water beyond the tide flats. An immature male was collected August 24, 1906.

Demiegretta sacra (Gm.).

The blue reef heron was seen but once, near Santa Fé.

Nycticorax manillensis Vig.

A small flock of Manila night herons was noted.

Butorides javanica (Horsf.).

Abundant in mangrove swamps.

Dendrocygna arcuata (Horsf.).

Ducks, all of this common species, were obtained on a small shallow pond near the eastern coast of the island.

Fregata ariel (Gould).

This graceful bird was first observed on September 5, 1906, when three individuals flew over, passing from east to west followed at about 100 yards by four more, one of which was killed; a single bird was seen two days later. The natives say that this bird "eats wind" and that it never alights; the native name on Bantayan is "con-pi-sao'." The specimen collected was a male; length, 28.8 inches; extent of wings, 63.0 inches; bill gray; gular pouch white with some scarlet wash.

Circus melanoleucus (Forster).

A fine adult male of this marsh hawk was killed in a "cogon" grass field on September 3, 1906.

Haliaëtus leucogaster (Gm.).

Fairly abundant.

Haliastur intermedius Gurney.

Abundant.

Elanus hypoleucus Gould.

An adult specimen was killed in a bamboo, September 17, 1906.

Cacatua hæmaturopygia (P. L. S. Müller).

One specimen; rare.

Tanygnathus lucionensis (Linn.).

One specimen; rare.

Eurystomus orientalis (Linn.).

One specimen; rare.

Alcedo bengalensis Briss.

A female taken September 8, 1906; very rare.

Halcyon chloris (Bodd.).

One male; not uncommon.

Merops philippinus Linn.

An hour before sunset numbers of bee-birds often appeared near the town, moving in small circles and with a slow progressive motion from east to west. On such occasion there were probably not less than 300 individuals over an area of 20 acres, presenting a very pretty sight. Two specimens were secured.

Caprimulgus manillensis Wald.

Two females were secured in an old field.

Salangana whiteheadi Grant.

Swifts were observed on September 3, 1906, only, when two specimens of the above species were secured.

Cacomantis merulinus (Scop.).

Two specimens.

Eudynamis mindanensis (Linn.).

A male of August 27, 1906, is in nearly adult black plumage, but retains a few barred feathers on breast, flanks, and wing coverts.

Centropus viridis (Scop.).

Fairly common.

Centropus javanicus (Dumont).

Rare; one specimen.

Pitta atricapilla Less.

One male was taken August 23 and another August 27, 1906; the species appears to be rare in this island. It is known here as "wo-ha'."

Hirundo javanica Sparrm.

Fairly common.

Cyornis philippinensis Sharpe.

Rare; a male taken August 30, 1906.

Hypothymis occipitalis (Vig.).

Rare; one male taken.

Rhipidura nigritorquis Vig.

Abundant.

Lalage niger (Forster).

Abundant.

Iole guimarasensis Steere.

The fruit thrush of Bantayan belongs to the above variety. Its greater size, darker and less reddish throat and more pronounced shaft lines distinguish this bird from *Iole philippensis*. Five males from Bantayan collected in September, 1906, measure as follows: Wing, 4.06 to 4.18 (average 4.11); exposed culmen, 0.82 to 0.92 (average 0.88). Five males of *Iole philippensis*, collected at Toledo, Cebu in September and October, 1906, measure as follows: Wing, 4.00 to 4.09 (average 4.04); exposed culmen, 0.78 to 0.80 (average 0.79).

A female taken September 14, 1906, has nearly the entire forehead white, washed with pale yellow.

Copsychus mindanensis (Gm.).

Not uncommon; one specimen.

Pratincola caprata (Linn.).

Apparently rare; one female taken September 3, 1906.

Orthotomus castaneiceps Walden.

Extremely abundant; a fully grown bird of the year taken September 11, 1906, is dull green above and white below; the breast slightly gray; chestnut of adult plumage just showing around eye and a few gray plumes in neck. Adults do not differ from specimens collected in Masbate and Ticao. The native name is "tag-ua-ti'."

Cisticola exilis (Vig. & Horsf.).

This small grass warbler is probably the most abundant avian species on the island. A bird just from the nest was taken August 21, 1906.

Acanthopneuste borealis (Blas.).

The Northern willow warbler was very rare; a female was taken September 8, 1906, and another individual was seen a few days before.

Artamus leucorhynchus (Linn.).

Abundant.

Otomela lucionensis (Linn.).

The common shrike of the Philippines is known in Bantayan as "te-ti'-bi-as."

Cinnyris jugularis (Linn.).

Specimens of this species from Bantayan are slightly orange below the black breast. Abundant in coconut groves but no other species of *Nectariniidæ* was detected.

Anthus rufulus Vieill.

Fairly abundant; a male and a female were preserved.

Munia jagori Martens.

Not common.

Oriolus chinensis Linn.

Abundant. The native name is "tu-li-hao'."

Dicrurus mirabilis Wald. and Layard.

The ovary of a female taken August 28, 1906, contained a large egg and a young bird just able to fly was captured September 3, 1906. The adults taken do not differ from Ticao and Cebu specimens.

Sarcops melanonotus Grant.[2]

Not common; the single specimen preserved belongs to the above recently described variety.

Lamprocorax panayensis (Scop.).

Just before sunset on September 8, 1906, while looking for goatsuckers in an old cornfield, numbers of Panay starlings were noted flying in straight converging lines. The birds were in pairs or in flocks of from 3 to 30 individuals while near the close of the flight two flocks were estimated to contain 130 and 150 birds respectively. The average flock contained some 15 birds. Later investigation disclosed what I had expected to find, a night roost of these birds in a clump of bamboos and mangrove trees situated on the margin of a salt water swamp. In all 68 flocks were counted or estimated with a total of 1,059 birds, which was not over a third of the number actually reaching the roost.

Corone philippina (Bonap.).

Abundant.

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[2] *Bull. B. O. C.* (1906), **16**, 100.

THE BIRDS OF BOHOL.

By Richard C. McGregor.

INTRODUCTION.

Bohol Island, 1,441 square miles in area, is nearly circular in outline and its coast is little broken by bays or inlets, but there are more than 60 small islands near it, mostly to the north and northwest. There are no mountains in Bohol, but sharpe ridges of old coral limestone are found in the vicinity of Sevilla and Guindulman. On these ridges grows the only forest in the island. If any extensive forest ever existed on level ground, it has long since been cut. I was told that in the interior there are large areas of rolling land covered with tall cogon grass.

The first list of Bohol birds is that published by Tweeddale[1] based on the collections made by Mr. A. H. Everett and his brother. The Everetts went to Talibon on the northern coast of Bohol and evidently found no suitable collecting ground. Tweeddale says:

> "Mr. Everett stopped for a week at Talibon, on the north coast of the island, and then left for Palawan while his brother proceeded to the interior of the island to collect. There he found a country covered with grass 12 feet high, and with no forest except on the tops of a few hills. Birds were scarce; and he had to return stricken with fever."

The collection made by the Everetts contained examples of 47 species. The next collectors to visit the island were members of the Steere Expedition, but they seem to have taken few birds. Worcester[2] states that Steere and his collector, Mateo Francisco, went to Bohol for corals; the 14 species listed for "Bojol" by Steere[3] are common forms and 7 of these were not contained in the Everett collection.

In March, 1906, Messrs. Celestino and Canton, assistants in the Bureau of Science, were sent to Bohol and in May the author joined them at Tagbilaran, to find that valuable collections of birds had been made at Corella, Sevilla, and Balilijan, where small patches of forest had been found on steep coral rock hills. Collecting in the vicinity of Tagbilaran being practically useless because of the total lack of forest, we moved to Guindulman, where we found a small forested area on the top of a limestone ridge. The species collected here were much the same as those already obtained near Sevilla, but a number of important additions were made to our list.

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[1] *Proc. Zoöl. Soc.* (1878), 708–712.

[2] The Philippine Islands and their people. New York (1898), 303.

[3] List Phil. Bds. Ann Arbor (1890), 5–27.

For the sake of completeness I have included in the present list all species recorded by Tweeddale and Steere as well as the 91 additional species obtained by us; the latter are indicated by an asterisk (*) following the name. I have also indicated the few species not seen by us and have given references to all the records by Tweeddale and by Steere. Five of the species appear to be new and are described as *Turnix celestinoi, Phapitreron albifrons, Otus boholensis, Zosterops læta*, and *Eudrepanis decorosa*.

Before giving the list of birds known from Bohol I will indicate briefly the evidence in favor of uniting this island with Samar-Leyte[4] rather than with Cebu. Worcester[5] has pointed out that the affinities of the Bohol faunæ are with Leyte and not with Cebu. The much greater amount of material now available fully confirms his opinion. I will first give a list of characteristic genera which, so far as known, have no representatives in Cebu, but which are now known from Bohol and from the islands east and south of it (Samar-Leyte, and Mindanao).

CHARACTERISTIC GENERA REPRESENTED IN BOHOL AND ABSENT FROM CEBU.

Hydrocorax.
Penelopides.
Pyrotrogon.
Chrysocolaptes.
Rhinomyias.
Poliolophus.
Zosterornis.
Macronus.
Orthotomus.
Eudrepanis.
Arachnothera.

In addition to the striking difference shown by the above list is the evidence afforded by several genera common to the two islands, but having well-marked representative species.

GENERA COMMON TO CEBU AND BOHOL WITH THE REPRESENTATIVE SPECIES KNOWN FROM EACH ISLAND.

CEBU.	BOHOL.
Phapitreron frontalis.	*P. amethistina.*
Phapitreron nigrorum.	*P. albifrons.*
Loriculus chrysonotus.	*L. worcesteri.*
Yungipicus maculatus.	*Y. leytensis.*
Cryptolopha cebuensis.	*C. olivacea.*
Artamides cebuensis.	*A. kochi.*
Hyloterpe winchelli.	*H. apoensis.*
Zosterops everetti.	*Z. læta.*
Dicæum pallidior.	*D. cinereigulare.*
Prionochilus quadricolor.	*P. inexpectatus.*

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[4] The differences between the birds of Samar and Leyte are so unimportant that for the purpose of this paper these islands are treated as one.

[5] *Proc. U. S. Nat. Mus.* Wash. (1898), **20,** 580.

The foregoing lists are sufficient to show the fundamental difference between the birds of Cebu and Bohol, while the following lists are calculated to indicate that Bohol is closely related to Samar-Leyte and less closely to Mindanao:

CHARACTERISTIC SPECIES FOUND IN BOHOL AND SAMAR-LEYTE.

Loriculus worcesteri.
Hydrocorax semigaliatus.
Penelopides samarensis.
Yungipicus leytensis.
Chrysocolaptes rufopunctatus.
Hypothymis samarensis.
Zosterornis nigricapitatus.
Orthotomus samarensis.

CHARACTERISTIC SPECIES FOUND IN BOHOL, SAMAR-LEYTE, AND MINDANAO.

Phapitreron amethystina.
Pyrotrogon ardens.
Centropus melanops.
Pitta steerei.
Artamides kochi.
Poliolophus urostictus.
Orthotomus frontalis.
Hyloterpe apoensis.
Rhabdornis minor.
Dicæum cinereigulare.
Prionochilus olivaceus.
Arachnothera philippinensis.
Dicrurus striatus.

LIST OF THE BIRDS OF BOHOL.

Gallus gallus (Linn.).*

The jungle fowl was abundant in the various localities visited; it is known to the natives as "ma-noc'-i-has'."

Turnix celestinoi McGregor.*

A single hemipode was killed on a grassy hill near Guindulman. The species was not observed in any other part of Bohol and it is probably rare as it seems to be unknown to the natives. This species is somewhat similar to *Turnix whiteheadi* but differs in being darker and having a larger bill and longer wing and tarsus.

Osmotreron vernans (Linn.).

Osmotreron vernans TWEEDDALE, Proc. Zool. Soc. (1878), 710.

The green "pu-nai" was abundant in all localities visited and was usually found feeding in shrubs.

Phapitreron amethystina Bp.*

Four examples of the amethyst dove, obtained at Sevilla, differ from two others taken near Manila in having the chin and throat slightly darker and more ruddy and the forehead darker. A female from Sevilla, taken March 23, has one of the longer under tail-coverts entirely white.

Phapitreron albifrons new species.

Phabotreron brevirostris STEERE, List Phil. Bds. (1890), 24.

Specific characters.—Belonging to the small billed group of this genus but distinguished from all other known species by the white forehead and chin and the brown subocular line.

Type.—No. 11490, ♂, Bureau of Science Collection; Tagbilaran, Island of Bohol, P. I.; May 1, 1906; Celestino and Canton collectors.

Description of type.—General color brown, much darker above, with iridescent reflections most pronounced on nape, mantle, and breast; merging rather abruptly into dark gray of crown; occiput, nape, and sides of head, ruddy-brown; from gape a narrow brown line passing below the eye with a wider white line underneath, both lines reaching beyond ear-coverts; chin, white, gradually changing to gray on throat and ochraceous on breast and abdomen; under tail-coverts and a wide band at end of tail, pale French gray; wings, uniform with the back; primaries, with a narrow light brown edge on outer web. With the bird held toward the light the occiput and nape are glossed with green, followed by a patch of metallic blue, this followed on interscapulars by a wide band of metallic green extending to sides of neck and narrowly bordered behind by blue; the wings and remaining upper parts have a dull green gloss; with the bird held away from the light the green changes to purple and this metallic color shows also on throat, breast and sides of neck. Length in flesh, 9.2 inches; wing, 4.80; tail, 3.20; culmen from base, 0.64; tarsus, 0.66.

This distinct species is most closely related to *Phapitreron brevirostris* of Mindanao, but its white forehead and brown subocular line distinguish it at once from all previously described species. Our first specimens were collected at Sevilla and Loboc and it was observed by the roadside daily during our journey from Tagbilaran to Guindulman; near the latter town it was often seen in company with *Osmotreron vernans* feeding in shrubs which grow in open country. It was found in forest as well, but was then more difficult to detect owing to its quiet habits and the protection of thick foliage. In this species the terminal half of bill is black; basal half of bill, skin around eyes, and feet, dull crimson; irides, brown; nails, gray. A hard shelled egg was taken from a female bird killed June 7 and another egg was obtained in the same way June 11. The latter egg measures 1.06 by 0.82 and is pure white in color. In Bohol this bird is called the "li-mú-con."

Leucotreron leclancheri (Bp.).*

Specimens of Leclancher's dove were taken at Tagbilaran and at Sevilla.

Muscadivora ænea (Linn.).*

The "baud" was not observed in abundance but a few specimens were taken at Sevilla and Guindulman.

[**Myristicivora bicolor** Scop.

Myristicivora bicolor WORCESTER AND BOURNS, Proc. U. S. Nat. Mus., **20,** 551, species No. 29; MCGREGOR AND WORCESTER, Hand-List Phil. Bds. (1906). 12.

In the papers quoted above, this species is given as being found in Bohol but I find no original record of the species from this island and it was not observed by us.]

Macropygia tenuirostris Bp.*

The slender-billed cuckoo dove was not uncommon. An example with several white primaries and secondaries in each wing was seen in flight but was not secured. One specimen was taken in Sevilla.

Streptopelia dussumieri (Temm.).

Turtur dussumieri TWEEDDALE, Proc. Zool. Soc. (1878); 711; STEERE List Phil. Bds. (1890), 24.

The "tuc-mó" was abundant in shrubs and bamboo clumps about the borders of rice fields and grass lands.

Chalcophaps indica (Linn.).*

The Indian bronze-winged dove is known to the Boholanos as "ma-ná-tad." Several specimens were collected.

Poliolimnas cinereus (Vieill.).*

This rail was obtained at Sevilla and at Guindulman.

Amaurornis olivacea (Meyen).*

This species was obtained at Tagbilaran and Guindulman. It is often seen in very dry localities and appears to be quite independent of marsh land.

Amaurornis phœnicura (Forster).*

No specimen of this species was obtained but it was seen several times and I have no hesitation in recording it as an inhabitant of Bohol.

Gallinula chloropus (Linn.).*

Three specimens in perfect plumage from Sevilla. This species is known to the natives of Bohol as "ca-rab' i-tu-mon'."

Gallicrex cinerea (Lath.).*

The "tu-yud'," was abundant near Guindulman where one was killed.

Porphyrio pulverulentus Temm.*

This odd species was seen many times before a specimen was obtained. It was found feeding in a very restricted area of old, flooded paddy near Guindulman. Here it was completely hidden from view until it took flight and plunged into a thick growth of grass some ten or twelve feet tall, where of course it was useless to follow it. When not aware of danger it walked about, searching for food among the matted aquatic plants, in the manner of the smaller rails. The tail was carried erect, but was frequently moved with a downward jerk, giving the bird an extremely nervous appearance. Live specimens are occasionally seen in the Manila markets and I am told that they are easily tamed, but become a nuisance to anyone owning chickens, as with their powerful beaks they kill all small chickens coming within their reach.

A female was taken June 20. Bill and irides red; legs reddish brown; nails gray. The native name of this species is "ca-rab' a-bu-hon'."

Podicipes philippinensis (Bonn.).*

Two specimens of the Philippine grebe were obtained near Sevilla where the species is known as "ga-mao'."

Sterna boreotis (Bangs).

Sterna bergii TWEEDDALE, Proc. Zool. Soc. (1878), 712.

Observed at Tagbilaran.

Arenaria interpres (Linn.).

Strepsilas interpres TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Squatarola helvetica (Linn.).*

Two specimens of the black-bellied plover were taken at Tagbilaran, May 9.

Charadrius fulvus (Gm.).

Charadrius fulvus TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Ochthodromus geoffroyi (Wagl.).

Eudromias geoffroyi TWEEDDALE, Proc. Zool. Soc. (1878), 711.

A pair from Tagbilaran, May 9. The male has put on the breeding dress while the female is still in the plain brown and white winter plumage.

Ochthodromus mongolus (Pall.).

Eudromias mongolus TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Ægialitis dubia (Scop.).

Ægialitis dubia TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Ægialitis peroni (Bp.).

Ægialitis peroni TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Ægialitis alexandrina (Linn.).

Ægialitis cantiana TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Ægialitis cantianus STEERE, List Philip. Bds. (1890), 25.

Not seen by us.

Numenius variegatus (Scop.).*

Tagbilaran, May 8, a male.

Numenius cyanopus Vieill.*

Tagbilaran, May 8. Male, length, 23 inches; wing, 11.5; culmen, 5.65; tarsus, 3.20. Female, length, 25 inches; wing, 12.00; culmen, 6.90; tarsus, 3.64.

Limosa novæ-zealandiæ Gray.

Limosa lapponica TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Tagbilaran, May 8, five specimens.

Totanus eurhinus (Oberh.).*

A female from Tagbilaran, May 8. Measurements are here given of seven specimens in the Bureau of Science Collection.

Measurements of Totanus eurhinus.

Sex.	Locality.	Date.	Wing.	Tail.	Exposed culmen.	Tarsus.	Middle toe with claw.
♂	Cuyo	Jan. 12, 1903	6.25	2.40	1.80	1.92	1.34
♂	Cebu	Nov. 25, 1906	6.00	2.52	1.77	1.95	1.30
♀	Cuyo	Jan. 11, 1903	5.95	2.34	1.70	1.86	1.40
♀	do	do	6.40	2.45	1.88	1.98	1.31
♀	do	Jan. 12, 1903	6.20	2.60	1.80	1.80	1.26
♀	Bohol	May 8, 1906	6.00	2.46	1.76	2.04	1.32
♀	Cebu	Nov. 19, 1906	6.30	2.55	1.84	1.84	1.30

Helodromas ochropus (Linn.).*

Three specimens of the green sandpiper were taken at Sevilla, March 22 to April 16.

Heteractitis brevipes (Vieill.).

Totanus incanus TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Five specimens in summer plumage from Tagbilaran, April 30, and four specimens in winter plumage, April 30 to May 9.

Actitis hypoleucus (Linn.).

Tringoides hypoleucos TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Terekia cinerea (Güldenst.).

Terekia cinerea TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Taken by Everett in northern Bohol; not seen by us.

Glottis nebularius (Gunn.).*

A pair from Tagbilaran, May 8. The male has assumed a large part of the summer dress while the female is still in winter plumage.

Rhyacophilus glareola (Gm.).

Rhyacophilus glareola TWEEDDALE, Proc. Zool. Soc. (1878), 711.

Two specimens from Sevilla.

Limonites ruficollis (Pall.).

Tringa albescens TWEEDDALE, Proc. Zool. Soc. (1878), 712.

Two small sandpipers were killed on May 25 from a large flock which was feeding about a flooded salt works located a short distance east of Loay. These specimens are in nearly perfect summer plumage and agree with the description of the above species.

Limicola platyrhyncha (Temm.).

Limicola platyrhyncha TWEEDDALE, Proc. Zool. Soc. (1878), 712.

Collected by Everett in northern Bohol; not seen by us.

Gallinago gallinago (Linn.).

Gallinago scolopacina TWEEDDALE, Proc. Zool. Soc. (1878), 712.

Collected by Everett in northern Bohol; not seen by us.

Dissöura episcopus (Bodd.).

Melanopelargus episcopus STEERE, List Phil. Bds. (1890), 27. (Bojol.)

Bohol is omitted from the list of localities given for this species in McGregor and Worcester's Hand-list, p. 31. I did not observe the species in Bohol, but many of the natives told me of it, and Celestino, who is familiar with the species, did see it.

Pyrrherodias manillensis (Meyen).*

The Manila heron is well known to the natives as "la-paí." It was common in old flooded rice fields in the vicinity of Guindulman where an adult female was taken, June 3.

Ardea sumatrana Raffles.*

June 8 a trip was made to the town of Cogtang[6] on the west coast five miles from Guindulman for the purpose of visiting some small islands near there. The islands proved to be low and covered with a heavy growth of mangroves where, except *Cinnyris jugularis*, no land bird was seen. However, two specimens of the great slaty heron were killed from fish corrals where they had been sampling the catch. The species is known locally as "du-ŭng" and is said to appropriate a considerable number of fish. As the natives have no firearms, little or nothing can be done to prevent the depredations of the herons. The following data were taken from the two birds mentioned above. Male; iris, red; bill, black, lower mandible, yellow near tip, becoming white toward its base; legs and claws, blackish brown. Total length, 67.0 inches; wing, 19.30; tail, 7.25; tarsus, 6.70; culmen, 7.10. Female; length, 55.0; wing, 18.0; tail, 6.40; tarsus, 6.00; culmen, 6.45.

Mesophoyx intermedia Wagl.

Ardea intermedia STEERE, List. Philip. Birds (1890), 26 (Bojol).

Steere appears to be only person to have recorded this species for Bohol.

Egretta garzetta (Linn.).

Herodias garzetta TWEEDDALE, Proc. Zool. Soc. (1878), 712.

A female from Tagbilaran.

Demiegretta sacra (Gm.).

Ardea jugularis STEERE, List. Phi. Bds. (1890), 26.

The reef heron was fairly common near Guindulman and on tide flats between that town and Tagbilaran. The name "tă-bon" is sometimes used to designate this species but is usually applied to *Bubulcus coromandus* only.

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[6] On a map I find the above spelling given but the natives certainly pronounced it Cug-tŭng. See *Atlas of the Philippine Islands*, U. S. Coast and Geodetic Survey, Special Pub., No. 3 (1900), map 23.

Nycticorax manillensis Vig.*

An adult specimen from Sevilla, March 19; not uncommon. The natives of Bohol are extremely afraid of a spirit which they call the "cuak cuak" and at night they carefully close doors and windows to shut it out. When the night herons fly over in the early evening uttering their weird call the natives say: "There is the 'cuak cuak,' be careful."

Butorides javanica (Horsf.).*

Abundant.

Bubulcus coromandus (Bodd.).

Bubulcus coromandus TWEEDDALE, Proc. Zool. Soc. (1878), 712.

Oates[7] in his description of the summer plumage of this species says: "The whole plumage white except the head, neck, breast and dorsal plumes which are rich golden buff." In Philippine specimens, however, the dorsal plumes are much lighter than the head and of a different color, being delicate vinaceous pink washed with brown. Sharpe[8] points out this difference in the following words: "The entire head, neck, throat, and fore-neck bright orange; the dorsal plumes of a distinct vinous sienna, with a golden tinge, the feathers of the fore-neck also tinged with the same color."

I have heard natives relate a number of fanciful tales respecting the nesting habits of this species; some aver that it does not lay eggs and other say that its nest is to be found only under the water. An egg of this species is reputed to bring the possessor good luck and the finding of a nest brings riches to the finder. The most elaborate story I have heard is current among Tagalogs and runs as follows:

The "ta-gắc ca-la-baó" builds its nest in high trees over water. The nest can only be seen by its reflection in the water. To secure an egg, supposing you have found a nest, climb the tree always looking at the aqueous image. In this way you may reach the nest and secure the eggs which confer upon the possessor the power of becoming invisible.

Several hundreds of these birds nested in a patch of giant grass near Guindulman. The nests examined were flat and 8 to 10 inches in diameter and were supported by grass stems at about 6 feet above the water. The natives rob this colony several times a year, but the eggs are a poor article of diet. From a large series obtained June 13, twenty eggs have been selected and measured; the length varies from 1.58 inches to 1.96 and the width varies from 1.20 to 1.39. Five eggs taken at randum measure: 1.86 by 1.38; 1.88 by 1.33; 1.82 by 1.25; 1.79 by 1.36; 1.61 by 1.20. In color the eggs are very pale blue. Hume[9] gives interesting notes on the nesting habits and Oates[10] describes and figures eggs of this species from India and Ceylon.

Ardetta cinnamomea (Gm.).*

A female from Guindulman, June 16.

Dendrocygna arcuata (Horsf.).

Dendrocygna vagans TWEEDDALE, Proc. Zool. Soc. (1878), 712.

The "ga-kít" occurs in small numbers at Sevilla, Guindulman and probably at other localities on the island where conditions are favorable.

Circus melanoleucus (Forster).* (Plate 1.)

An adult specimen of this fine marsh hawk from Sevilla.

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[7] Bds. Brit. Burmah, London (1883), **2,** 251.

[8] Catalogue Bds. Brit. Mus. (1898), **26,** 218.

[9] Nests and Eggs Ind. Bds. (1890), **3,** 247.

[10] Cat. Eggs Brit. Mus. (1902) **2,** 130, pl. v., fig. 2.

Spilornis panayensis Steere.*

The Panay serpent-eagle is fairly abundant and is well known to the natives as the "si-cúb." Specimens were obtained at Sevilla and at Guindulman.

Butastur indicus (Gm.).

Butastur indicus TWEEDDALE, Proc. Zool. Soc. (1878), 709.

Collected by Everett in northern Bohol; not seen by us.

Haliaëtus leucogaster (Gm.).*

The white-bellied fish-eagle was often seen on the coast; one specimen was killed on a fish-corral at Guindulman.

Haliastur intermedius Gurney.

Haliastur intermedius TWEEDDALE, Proc. Zool. Soc. (1878), 709; STEERE, List Philip. Bds. (1890), 7.

The "ba-nog" is common in Bohol.

Elanus hypoleucus Gould.*

A single specimen of this kite was obtained at Guindulman. Irides, light yellow; bill, black; cere, waxy-yellow; legs and feet, bright chrone-yellow; claws, black.

Microhierax erythrogenys (Vigors).*

One male specimen from Guindulman, June 7. Wing, 4.4 inches. As the inner webs of the primaries are barred with white this specimen can not be referred to *M. meridionalis* Grant, which has the inner webs of the primaries uniform black in both sexes, although the latter species is the one to be expected in Bohol.

Otus boholensis new species.*

Type.—♀, No. 11500, Bureau of Science Collection; Sevilla, Island of Bohol, P. I.; March 31, 1906; Celestino and Canton, collectors.

Description of type.—Crown, nape, and interscapular area, conspicuously blackish, the feathers sparingly vermiculated and notched with sandy buff; basal portion of a few feathers sandy buff forming a narrow and hidden nuchal band; forehead, whitish, the whitish marking continued as a wide band over each eye to tips of ear tufts on inner webs, outer webs, blackish spotted with fulvous, these white bands more or less broken by fine vermiculations of dark brown; loral plumes, whitish with blackish tips; ear-coverts, grayish shaded with fulvous and narrowly barred with dark brown, the hinder ear-coverts tipped with black forming a short band; side of neck, whitish with fine blackish cross lines and wide blackish tips to the feathers; behind ear-coverts an imperfect ruff of whitish feathers with wide terminal or subterminal black bars; chin, whitish; feathers of throat somewhat modified in continuation of the ruff; breast, sides, and abdomen, rufescent-cinnamon with fine vermiculations and irregular shaped median stripes of blackish-brown, each feather with one or two roundish spots of light buff on each web; under tail-coverts, light, sandy buff with a few wavy blackish lines near their tips; legs, sandy buff crossed with distinct, wavy, blackish lines; feathering of tarsi extending nearly to basal joints of toes; primaries, dark brown, the outer webs with large, clear and distinct spots of sandy buff, 6 in number on short first primary, and corresponding faint bars on inner webs; secondaries, dark brown with sandy buff bars which are somewhat obscured by darker vermiculations; the primary coverts resemble the secondaries and the first quill of alula is marked like the primaries; secondary coverts, scapulars and back, vermiculated with sandy buff, light buff, and blackish-brown and marked with large, irregular, blackish-brown spots; under wing-coverts, nearly white, inner ones uniform, the outer buff mottled with blackish; edge of wing, white; tail, dark brown, mottled with sandy buff and with 7 or 8 poorly defined bars of sandy buff. Wing, 6.12 inches; tail, 3.22; tarsus, 1.18; culmen from base, 0.95; culmen from anterior margin of cere, 0.62; ear-tuft, 1.15.

This bird is clearly allied to *Strix lempiji* Horsfield and doubtless it is closely related to *Otus everetti* with which it should be compared. The type was the only individual observed.

Cacatua hæmaturopygia (P. L. S. Müller).*

The collection contains a specimen of the "a-bū-cay" from Sevilla and one from Guindulman in which localities it is not uncommon. From the vicinity of Tagbilaran it appears to be entirely absent.

Prioniturus discurus (Vieill.).*

This racket-tailed parrot was obtained at Sevilla and at Guindulman. Its native name is "ca-gāc."

Tanygnathus lucionensis (Linn.).*

The "pi-cōy" occurs in all the forested areas but is not abundant.

Loriculus worcesteri Steere.

Loriculus hartlaubi? TWEEDDALE. Proc. Zool. Soc. (1878), 709.

Abundant in coconut groves near Guindulman. The species in Bohol is *L. worcesteri* not *L. apicalis*. Native name, "co-sī."

Eurystomus orientalis (Linn.).*

One specimen from Sevilla; the species was also observed near Guindulman.

Pelargopsis gigantea Walden.*

This large kingfisher was rare in the parts of the island visited by us. Two individuals were seen near the beach at Guindulman and a few were observed about fish corrals at the town of Cogtang. Two specimens were collected.

Alcedo bengalensis Briss.

Alcedo bengalensis TWEEDDALE, Proc. Zool. Soc. (1878), 709.

Rare; one specimen from Sevilla, March 19.

Halcyon gularis (Kuhl).*

The white-chinned kingfisher was not abundant but was obtained near Guindulman and at Sevilla.

Halcyon winchelli Sharpe.*

This species is represented by a single specimen taken near Guindulman on June 4.

Halcyon chloris (Bodd.).

Sauropatis chloris TWEEDDALE, Proc. Zool. Soc. (1878), 709.

The "ti-ca-rōl" was abundant in coconut groves and bamboo clumps. Celestino collected eggs of this species at Tagbilaran, April 26.

Hydrocorax semigaliatus (Tweed.).*

This large hornbill was abundant near Sevilla but it was not seen in the vicinity of Tagbilaran. At Guindulman the "cau" was often heard calling in the forest a mile or two distant.

The natives say that the hornbill calls on the hour, from which arises its Spanish name, "reloj del monte." Of course the bird calls whenever it takes the notion to do so with no reference to the time of day.

A good series of both adult and young birds was secured. During May the adults were in almost perfect plumage but in June the old rectrices began to drop and the new, white tail feathers began to appear. In the adult the basal part of bill is red; terminal half of upper mandible and two-thirds of lower mandible, white; irides, pale yellow, legs, dark red; nails, blackish-brown. In the young bird the bill is crestless and black with a light yellow tip; irides-brown; legs and feet, yellowish-brown; nails, blackish-brown.

The Bohol specimens agree with the description of *H. semigaliatus.*

Penelopides samarensis Steere.*

The "tau-si" occurs in the same areas as *Hydrocorax.* Bohol specimens agree with descriptions of *P. samarensis* and are doubtless of this species.

Merops americanus P. L. S. Müller.*

One specimen from near Tagbilaran was collected May 24.

Merops philippinus Linn.

Merops philippinus TWEEDDALE, Proc. Zool. Soc. (1878), 709.

Three specimens from Guindulman where this species was frequently seen.

Caprimulgus manillensis Walden.*

A specimen of the Manila goatsucker taken at Sevilla, April 24, does not differ from specimens collected in the islands of Mindoro and Luzon.

Salangana whiteheadi (Grant).*

A female was taken at Tagbilaran, May 12.

Salangana troglodytes Gray.*

This small species was fairly common in Bohol and was often seen in company with Salvadori's swift. The native names "bû-ta bûta," meaning a blind one and "sai-aû," meaning the dancer, are applied to both swifts and swallows without discrimination. It seems probable that the former name was originally used for the swifts as the word blind characterizes most aptly their dodging, erratic flight.

Salangana marginata (Salvad.).*

Salvadori's swift was not uncommon near Guindulman. On June 5 it was found breeding in a large cave and a nest examined at that time contained young which were about to fly. In Bohol no groups of nests were observed like those already described by me.[11]

Tachornis pallidior McGregor.*

The paler palm swift is the most interesting of our finds among the *Cypselidæ* of Bohol. It was first detected on June 18 when a few individuals were found feeding about a clump of bamboo not far from Guindulman. Specimens from Bohol do not differ from the type.

Pyrotrogon ardens (Temm.).*

The Philippine trogon was obtained at Sevilla and at Guindulman.

Hierococcyx fugax (Horsf.).*

One female specimen from Sevilla, taken March 23.

Cacomantis merulinus (Scop.).

Cacomantis merulinus TWEEDDALE, Proc. Zool. Soc. (1878), 709.

This common cuckoo was obtained in various localities.

Eudynamis mindanensis (Linn.).*

One specimen from Tagbilaran.

Centropus viridis (Scop.).

Centrococcyx viridis TWEEDDALE, Proc. Zool. Soc. (1878), 709.

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[11] *Publications of the Bureau of Government Laboratories,* Manila (1905), 25, 14, Pl. 2.

Five specimens. A male from Tagbilaran, May 2, has a pure, white feather on the mantle and one wing feather partly white.

Centropus javanicus (Dumont).*

Four specimens from Sevilla and from Guindulman. This species has not been recorded from Bohol although so given in McGregor and Worcester's Hand-List.

Centropus melanops Lesson.*

The black-eyed cuckoo was abundant at Sevilla and at Guindulman.

Yungipicus leytensis Steere.*

This little woodpecker is represented by a single male specimen taken near Tagbilaran on April 27. In Bohol all species of woodpeckers are called "bá-toc."

Chrysocolaptes rufopunctatus Hargitt.*

Three males and three females were obtained in Bohol. Steere[12] describes *Chrysocolaptes samarensis* (= *C. rufopunctatus*) very aptly as "curiously intermediate between C. hæmatrebon and lucidus, having the back of one and the ventral surface of the other, but the crimson marking of the face separates it from either."

These three species are of nearly the same size but *rufopunctatus* has the heaviest and longest bill and *lucidus* has the shortest and most slender bill. *C. lucidus* is also distinguished by having the lower mandible light yellowish green, while in the two other species the bill is uniform black or blackish brown.

Thriponax pectoralis Tweed.*

Sevilla, April 17, one adult male in full plumage; Guindulman, May 30, and June 8, two adult males in worn plumage; June 2, one immature male in good plumage. In the three adult specimens a number of feathers on each side of the forebreast have narrow crimson tips.

Pitta erythrogaster Temm.*

The red-bellied pitta was observed at Guindulman only, where three specimens were taken in June.

Pitta atricapilla Lesson.*

The black-headed pitta was found to be abundant at all the points visited.

Pitta steerei Sharpe.*

An adult male of Steere's pitta was taken at Sevilla, April 17, an adult female was killed the next day, and a slightly immature female was taken April 7. At Guindulman but one bird was seen, a female, taken June 6.

Hirundo gutturalis Scop.*

Four immature birds from Sevilla, March 22.

Hirundo javanica Sparrm.

Hirundo javanica TWEEDDALE, Proc. Zool. Soc. (1878), 709.

A male and a female from Tagbilaran, April 25; a nest containing three heavily incubated eggs was found July 11. The nest was plastered to the roof of a small waveworn cave. The eggs are white, dotted with reddish and blackish brown, and a few under shell markings of lavender. The eggs measure 0.70 by 0.49; 0.70 by 0.49; 0.69 by 0.49.

Hirundo striolata Boie.*

This attractive swallow was first observed in Bohol by Celestino, who saw several individuals at Loboc on the Loay River; at Valencia, May 26, one specimen was killed near the church and the next day two were killed at Garcia Hernandez.

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[12] List. Phil. Birds (1890), 8.

At Jagna the species was abundant in front of the church and several specimens were taken. On our arrival at Guindulman, May 28, an incomplete nest of the mosque swallow was found on a rafter under the town hall. The nest was composed of mud with a thick lining of grass stems and bamboo shavings, upon which were arranged a great number of chicken feathers. Three fresh eggs were taken from this nest June 11; they are slender and rather sharply pointed at the smaller end; their respective measurements in inches are 0.89 by 0.58; 0.88 by 0.56; 0.90 by 0.58.

June 5 a small nesting colony of mosque swallows was found in a wide-mouthed cave near Guindulman. About a dozen nests were plastered against the overhanging rock wall and 20 feet or so above the floor of the cave, making it a matter of great difficulty to secure the eggs unbroken. The mud nests were lined with grass stems, coconut-tree bark, and other plant fibers, as well as with feathers, among which those of *Artamides* and the domestic fowl were recognized. Two eggs obtained by means of an improvised bamboo ladder were heavily incubated and measure 0.92 by 0.61 and 0.90 by 0.61, respectively. All of the eggs of *Hirundo striolata* taken by me were pure white and unspotted.

Hemichelidon griseisticta (Swinh.).*

Two specimens from Sevilla, April 3 and 19, respectively.

Cyornis philippinensis Sharpe.*

Abundant.

Hypothymis occipitalis (Vigors).

Hypothymis azurea STEERE, List Phil. Bds. (1890), 16.

This pretty blue flycatcher is represented in the collection by two males and a female.

Hypothymis samarensis Steere.*

A male and two females from Sevilla.

Rhinomyias ruficauda (Sharpe).*

Four specimens collected are immature. Sevilla, March 20, April 9 and 13; Guindulman, June 12. These are in every way similar to adult birds from Basilan (December and January) but lores and side of head are more or less washed with fulvescent brown like the pileum. In the male taken April 9 the greater coverts are tipped with light fulvous which character also seems to be one of immaturity.

Abrornis olivacea Moseley.*

One male from Sevilla, March 21; two males, June 2 and 11 and a female, May 30 from Guindulman. The female was nesting.

Rhipidura nigritorquis Vigors.

Leucocerca nigritorquis TWEEDDALE, Proc. Zool. Soc. (1878), 709.

The native name for this common flycatcher is "'ca-la-mang-tí-gon."

Artamides kochi Kutter.*

A female from Sevilla, March 23 and a male from Guindulman, June 12.

Lalage niger (Forster).

Lalage dominica TWEEDDALE, Proc. Zool. Soc. (1878), 709.

Abundant.

Iole philippensis (Gm.).

Iole philippinensis STEERE, List. Phil. Bds. (1890), 19.

The Philippine fruit-thrush, which is very abundant in Bohol, is called "tug-bi-á."

Poliolophus urostictus (Salvad.).*

Eight specimens from various localities in Bohol.

Pycnonotus goiavier (Scop.).

Ixus goiavier TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Pycnonotus goiavier STEERE, List. Phil. Bds. (1890), 19.

A nest of this species was found at Guindulman on May 30; it was situated in a bunch of tall grass in a river bed and contained two eggs.

Zosterornis nigrocapitata (Steere).*

A male and two females of the genus *Zosterornis*, taken at Sevilla, April 18, are referred to the above species.

Macronus mindanensis Steere.*

In the vicinity of Tagbilaran this species and the representative tailor-bird (*Orthotomus frontalis*) occur in great abundance. In low brush, in bamboo along roads, and in uncultivated land, even within town, these two species are always to be found and often in company. The *Macronus* is not a shy bird and is constantly busy searching for food in the lower parts of shrubs and among rank growths of weeds. Specimens from Bohol agree in size and coloration with specimens taken by Clemens in the Lake Lanao region, Mindanao.

Copsychus mindanensis (Gm.).*

Abundant.

Pratincola caprata (Linn.).

Pratincola caprata TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Apparently rare; a male from Sevilla, March 8 and a female from Guindulman, May 30.

Locustella ochotensis (Midd.).*

One specimen from Guindulman, May 29.

Acrocephalus orientalis (Temm. & Schl.).*

Several specimens of a reed warbler found breeding near Guindulman are similar to *Acrocephalus orientalis* but seem to be quite distinct from the common form found in the Philippines and they may represent a local resident race. However, owing to my slight acquaintance with this family I do not at present feel justified in giving the bird a name.

Dr. Chas. W. Richmond has kindly examined these specimens and writes that they are correctly named "as our knowledge of them stands at present. I judge from the dates that the species breeds in the Philippines, but it winters there also, and probably during the winter you will find not only resident birds but northern migrants, possibly associated together. If you can prove the resident birds to be smaller (I doubt if any color differences can be made out) than the migrants it may be desirable to recognize them by name."

Orthotomus frontalis Sharpe.

Orthotomus frontalis TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Very abundant in all parts of the island visited. At Tagbilaran the species was particularly noticeable, being one of the commonest species observed. In a young bird from Tagbilaran, May 4, the forehead and area about eyes are gray like the crown, the back and wings are less green than in the adult, and the lower parts are pure white.

Orthotomus samarensis Steere.*

A male specimen of the rare Samar tailor-bird secured at Sevilla, April 5 does not differ from a specimen taken by Dr. Mearns in Samar.

Cisticola cisticola (Temm.).

Cisticola cursitans TWEEDDALE, Proc. Zool. Soc. (1878), 710.

I include this species on the authority of Tweeddale as above, but no specimen was taken by us.

Cisticola exilis (Vig. and Horsf.).*

Four male specimens from Bohol agree with Sharpe's description of *Cisticola exilis* in breeding plumage and must be referred to that species. The native name is "pi-rot."

Megalurus palustris Horsf.*

Fairly abundant in all localities visited by us. An immature male in yellowish plumage was taken near Guindulman, June 16.

Megalurus ruficeps Tweed.

Megalurus ruficeps STEERE, List Phil. Bds. (1890), 20.

A male from Sevilla, April 2.

Acanthopneuste borealis (Blas.).*

One specimen of the northern willow warbler from Tagbilaran, May 4.

Artamus leucorhynchus (Linn.).

Artamus leucorhynchus TWEEDDALE, Proc. Zool. Soc. (1878), 709.

The swallow shrike is known to the Boholanos as "it-it."

Cephalophoneus nasutus (Scop.).

Lanius nasutus TWEEDDALE, Proc. Zool. Soc. (1878), 709.

Very abundant; almost invariably found perched near the top of bamboo clumps.

Otomela lucionensis (Linn.).

Lanius lucionensis TWEEDDALE, Proc. Zool. Soc. (1878), 709.

The four specimens collected, March 29 to April 24, are typical examples of *O. lucionensis*.

Hyloterpe apoensis Mearns.*

Grant[13] in reporting on a collection of birds from Mindanao includes the thickhead of Samar, Leyte, Dinagat, and Basilan with the species recently described from Mount Apo, Mindanao. Eleven specimens from various localities in Bohol agree in every way with a male in the Bureau of Science collection which was taken on Mount Apo by Mearns. Between *Hyloterpe apoensis* and *H. philippinensis* the most obvious differences are the longer bill and duller green back of the latter species.

Rhabdornis minor Grant.*

This species is very distinct from *R. mystacalis*, having a much shorter bill. The species was found in some abundance at Sevilla and at Guindulman. Specimens from Bohol and from Basilan do not differ.

Zosterops læta, sp. nov.*

Specific characters.—Similar to *Zosterops basilanica* Steere but more yellowish above and the forehead and ear-coverts brighter; from *Zosterops everetti* Tweeddale it differs in lacking a black line under the eye and in having a much wider median, abdominal, yellow streak.

Type.—No. 5407, ♂, Bureau of Science Collection; Guindulman, Island of Bohol, Philippines; June 21, 1906; McGregor, Celestino, and Canton, collectors.

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[13] On the Birds collected by Mr. Walter Goodfellow on the Volcano of Apo and in its vicinity, in Southeast Mindanao, Philippine Islands: *Ibis* (1906), **6**, 475.

Description of type.—Above, bright yellowish-green, brighter and more yellowish on forehead and tail coverts; top of head a little brighter than back; wings and tail, blackish-brown edged with yellowish-green; edge of wing, sulphur-yellow; wing lining washed with yellow; a circle of silky white feathers about eye; no dusky spot on lores and no dark line under eye; entire side of head, yellow like the crown; below, sulphur-yellow, except sides of breast and sides of abdomen which are ashy-gray, lighter next the wide, median, yellow stripe. Lenght, 4.7 inches; wing, 2.36; tail, 1.70; tarsus, 0.64; exposed culmen, 0.40.

The female is scarcely different from the male.

This species was found in abundance at Sevilla and at Guindulman. While of the same style of coloration as *Z. everetti* and *Z. basilanica* the present species is quite distinct from either.

Dicæum papuense (Gm.).*

This common species was abundant in all parts of Bohol. A young male taken June 25 is dull blackish-brown above and pale gray below with no red in center of breast. A nest containing three fresh eggs was taken near Guindulman, June 18. The nest is 3½ inches in length with a diameter of 2 inches; it is cylindrical in form with the opening at the top and side. The materials are small bits of leaves fastened together by means of spider web. The eggs are palest blue with small spots and points of lilac and light brown scattered over the surface, but the markings are most numerous on the larger end; in one egg the spots are larger and form a wreath near the larger end. The eggs are very short and blunt but not equal-ended. They measure 0.58 by 0.46; 0.57 by 0.47; 0.51 by 0.46.

Dicæum everetti Tweed.*

Three male birds taken at Sevilla, April 5 to 18, are probably of the above species but they require comparison with specimens from other islands.

Dicæum cinereigulare Tweed.*

A fine series of orange-breasted flowerpeckers from Guindulman are very satisfactorily identified as of the above species, but unfortunately no typical specimens are at hand for comparison.

Dicæum pygmæum (Kittlitz).*

Very abundant.

Prionochilus olivaceus Tweed.*

A female bird taken at Sevilla, April 7, differs in no way from a specimen taken in Basilan and undoubtedly belongs to the above species.

Prionochilus inexpectatus Hartert.*

A male from Guindulman, June 4, agrees closely with Hartert's description of this species[14] and is similar to a specimen from Mariveles. The above male was the only individual of the species seen in Bohol.

Eudrepanis decorosa, sp. nov.*

Specific characters.—This species differs from *Eudrepanis pulcherrima* (Sharpe) and from *E. jefferyi* Grant in being much paler below, in wanting the red breast patch which is represented by a few red spots only, and in having the wing-coverts, tail, and upper tail-coverts metallic blue instead of metallic green.

Type.—No. 5255, ♂, Bureau of Science Collection; Guindulman, Island of Bohol, P. I.; June 4, 1906; McGregor, Celestino, and Canton, collectors.

Description of type.—Forehead back to opposite center of eye, metallic blue mixed with violet; crown, neck, sides of neck and mantle, dark green; rump, pale yellow; lores, velvety black; jaw, cheeks, and ear-coverts, metallic blue; chin, throat, and breast, pale yellow, reduced to a light yellow wash on abdomen, flanks, and under tail-coverts; middle of breast, marked with a few small spots of scarlet; wings, black; primaries bordered with white on inner webs and with no metallic color; all the wing-coverts and the secondaries widely margined with metallic blue, mixed with a little dark metallic green; tail, black, upper tail coverts and edges of retrices, metallic blue mixed with dark metallic green. Bill, legs, and claws black. Length in flesh, 3.8 inches; wing, 1.90; tail, 0.97 culmen from base, 0.72; tarsus, 0.55.

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[14] *Nov. Zool.* (1895), **2**, 64.

Female.—No. 11409, Bureau of Science Collection; Sevilla, Island of Bohol, P. I.; March 23, 1906; Celestino and Canton, collectors.

Differs from the female of *Eudrepanis jefferyi* in having the rump patch much lighter yellow. Upper parts, including wings, olive-green; top of head, mixed with dark gray; rump pale yellow; retrices, blackish with margins of dark, metallic green; chin, throat, breast, face, and sides of neck, whitish with a slightly streaked appearance from the dusky shaft lines; rest of lower parts, very pale yellow. Length in flesh, 3.5 inches; wing, 1.72; tail, 0.88; culmen from base, 0.72; tarsus, 0.51.

Eudrapanis pulcherrima was described as an *Æthopyga*[15] with the suggestion that it was probably generically distinct. The type locality is Basilan and the species is represented in the Bureau of Science collection by two males taken near Isabela, Basilan, January 16 and 28, 1907. In 1894 Grant[16] described a second species from Benguet Province, Luzon, as *Eudrepanis jefferyi* with the following characters: "The patch of metallic feathers behind the eye is steel-blue instead of green; the outer webs of the secondaries and scapulars are widely margined with *metallic* green, not olive-green; and the scarlet patch on the middle of the upper breast is more conspicuous."

A series, some 20 specimens, of this species was obtained by me at Irisan, Benguet, in April, May, and June, 1903. The most important of the characters assigned seems to be the metallic green of the secondaries but the size of the scarlet breast patch varies in specimens from the same locality and in the series before me it does not differ in the two species. In *E. decorosa* the patch is absent and represented by a few scarlet dots. I may note that the feathers forming the patch are red, with rather wide yellow tips, so that the patch always appears broken; the feathers are not edged with red as stated by Gadow.[17] I have stated that the yellow of throat and breast in *Eudrepanis jefferyi* and *Æthopyga rubrinota* is of about the same shade; in *Eudrepanis decorosa* the yellow is much paler, about as in *Æthopyga shelleyi.* Specimens of this very distinct species of sun-bird were obtained at Sevilla in March and at Guindulman in June.

Cinnyris sperata (Linn.).*

Several specimens from Guindulman and Tagbilaran.

Cinnyris jugularis (Linn.).

Cyrtostomus jugularis TWEEDDALE, Proc. Zool. Soc. (1878), 710.

This sun-bird was abundant in all parts of Bohol and as usual was found feeding in coconut trees as well as in forest and among the trees growing along rivers which make up the general tangle known as "mangle." The native name is "tam-si." In the series of males collected there is considerable variation in the color of the breast ranging from pure yellow to bright orange.

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[15] Sharpe: *Nature* (1876), **14,** 297.

[16] *Bull. Brit. Ornith. Club* (1894), **3,** 50; *Ibis* (1894), 513.

[17] Cat. Bds. Brit. Mus. (1884), **9,** 31.

Arachnothera flammifera Tweed.*

The flame-tufted spider-hunter was observed at Sevilla only, where four males were taken, March 27 to April 18.

Motacilla melanope Pall.*

A specimen from Sevilla, April 5.

Budytes leucostriatus Hom.

Budytes viridis TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Taken by Everett in northern Bohol; not seen by us.

Anthus rufulus Vieill.

Corydalla lugubris TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Anthus rufulus STEERE, List Phil. Bds. (1890), 21.

Abundant in all suitable localities.

Anthus gustavi Swinh.*

This species was observed at Sevilla only, where a male and two females were taken in March.

Alauda wattersi Swinh.

Alauda wattersi TWEEDDALE, Proc. Zool. Soc. (1878), 710.

A male, probably breeding, was killed on a grassy plain near Guindulman, June 8.

Munia jagori Martens.

Munia jagori TWEEDDALE, Proc. Zool. Soc. (1878), 710.

Munia atricapilla STEERE, List Phil. Bds. (1890), 23.

The "ma-ja" (English sound of j) occurs in great numbers and after the nesting season congregates in flocks when it inflicts much damage on standing rice. With a load of number 12 shot, 29 birds were killed from a small flock without causing any apparent decrease in its size; the larger flocks must contain several hundred individuals.

Uroloncha everetti (Tweed.).*

Rare in the localities visited by us; one specimen from Sevilla and another from Guindulman.

Oriolus chinensis Linn.

Broderipus acrorhynchus TWEEDDALE, Proc. Zool. Soc. (1878), 710.

At Tagbilaran and Sevilla the name "tu-li-haó" is applied to this species, while in Guindulman it is better known as "da-mud-laó," and the latter name was heard at Garcia Hernandez.

Dicrurus striatus Tweed.*

Abundant in all suitable localities. Two young, each 8 inches in length, from Sevilla, April 8, differ from the adult in having top of head dead black and under parts dark smoky brown with no gloss. A somewhat larger young bird (9.2 inches) was taken at Guindulman, June 1.

Sarcops melanonotus Grant.*

Sarcops calvus MCGREGOR AND WORCESTER, Hand-list Philippine Birds (1906), 109 (part).

Sarcops melanonotus GRANT, Ibis (1906), ser. 8, **6**, 469.

Birds from Bohol belong to the newly described race *Sarcops melanonotus* Grant, yet some individuals from that island are scarcely to be distinguished from true *S. calvus*. The two races of bald starlings present somewhat the same difficulty as do *Cinnyris aurora* and *C. jugularis*, there being islands in which the birds seem to be intermediate between the well-marked extremes. In certain islands not all the individuals can be referred to one race so that we have seemingly two varieties and birds intermediate between them existing in one restricted area. The dimensions of *Sarcops* vary considerably and appear to afford no means of distinguishing between the two races.

Measurements of Sarcops calvus, five males, and Sarcops melanonotus, ten males, showing extremes.

Species.	Wing.	Tail.	Bill from nostril.	Tarsus.
Sarcops calvus	4.83 to 5.18	4.20 to 4.70	0.77 to 0.90	1.06 to 1.25
Sarcops melanonotus	5.00 to 5.35	4.28 to 4.97	0.76 to 0.87	1.14 to 1.24

Lamprocorax panayensis (Scop.).

Calornis panayensis TWEEDDALE, Proc. Zool. Soc (1878), 710.

The Panay starling flourishes in great numbers under the native name of "ga-lang-si-ang'"; in Tagbilaran several dozen were nesting in the roof of the provincial government building and at Guindulman four individuals spent their time in carrying nesting materials into the end of the bamboos on the roof of a town house. June 15 a colony of several pairs was discovered in the crevices of a small, coral-rock island. The only accessible nest contained three full-grown young which left the nest when disturbed. One of these ended his flight in the water and was immediately picked up by a watchful *Haliastur*.

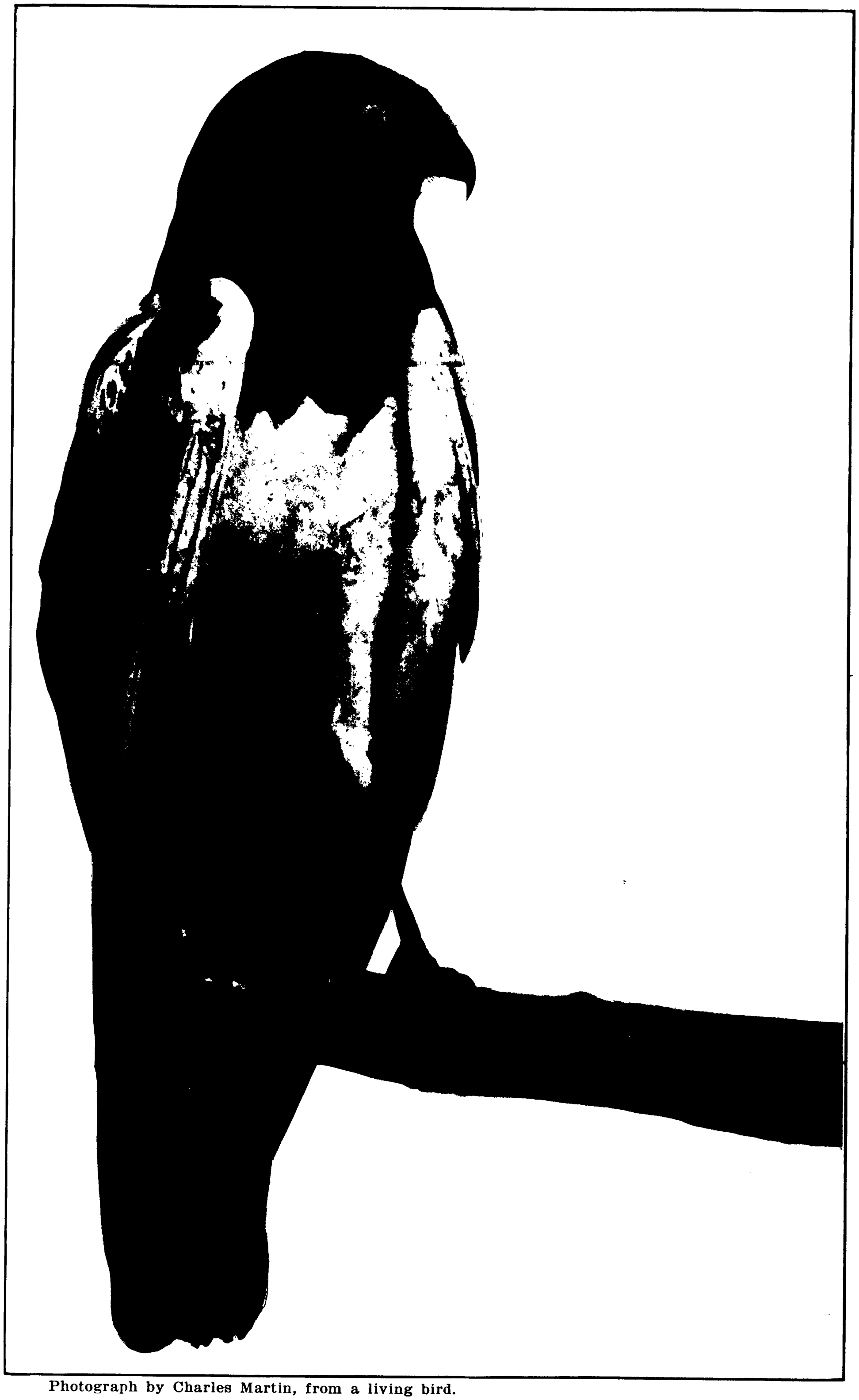
Corone philippina (Bp.).

Corvus philippinus TWEEDDALE, Proc. Zool. Soc. (1878), 710.

The Philippine crow occurs in Bohol in its usual abundance and one example from Tagbilaran was preserved. "Uak" is the only native name I have ever heard for the crow and that is the name used in Bohol.

ILLUSTRATION.

PLATE I. Circus melanoleucus (Forster). From a living bird taken near Manila. Photograph by Charles Martin.



Photograph by Charles Martin, from a living bird.

PLATE I. CIRCUS MELANOLEUCUS.

THE BIRDS OF BATAN, CAMIGUIN, Y'AMI, AND BABUYAN CLARO, ISLANDS NORTH OF LUZON.

By Richard C. McGregor.

INTRODUCTION.

The results of the study of a second collection of birds from some of the small islands north of Luzon are presented in this paper. In 1903 the author and his assistant visited Fuga and Calayan in the Babuyan group and secured a number of interesting species.[1] In May, 1907, through the courtesy of Major-General Leonard Wood, we were able to reach the more remote Island of Batan. From May 27 to June 16 collections were made on this island. On June 1 Governor-General Smith visited Batan in the steamer *Polillo,* and as temporary members of his party we spent a short time on Y'Ami June 17, and a few hours on Babuyan Claro June 18. On June 19 we landed at Port San Pio, Camiguin, where we remained until July 21 when we left for Aparri by native sailboat.[2]

Batan, the largest and most important of the Batanes group, is 24 square miles in area and is situated some 125 miles north from Cape Engaño on the Luzon coast. Its surface is broken by several groups of low mountains; the highest peak is Mount Iraya, 3,800 feet. This island is swept for nine months of the year by strong winds and typhoons, which prevent the growth of trees except in the protection of deep gulches. A great variety of resident birds was not expected nor found but several of the species are of great interest. It is worthy of note that such ubiquitous Philippine species as *Corone philippina, Oriolus chinensis, Sarcops calvus* and *Pycnonotus goiavier* are wanting, while the families Psittacidæ, Picidæ, Dicæidæ, Nectariniidæ and others are unrepresented. *Sphenocercus australis* and *Macropygia phœa* are found in both Batan and Calayan while *Zosterops batanis* and *Hypsipetes batanensis* are representatives of species found in Calayan. However, nothing like either *Centropus carpenteri* or *Terpsiphone nigra* is known from Calayan.

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[1] See *Bull. Philippine Mus.* (1904), 4, 1–34.

[2] Mr. A. Celestino, assistant collector, and Mr. E. Fenix, botanist, were with me on this entire trip, Mr. H. G. Ferguson, geologist, Bureau of Science, visited these islands at the same time. Reports on the geology and botany of Camiguin and Batan will appear in a later number of the Journal.

Camiguin, while more mountainous than Batan, is for the most part heavily wooded and it seemed reasonable to expect a much greater number of species than were found. Camiguin has an area of 61 square miles and is about 25 miles distant from Cape Engaño. Its avian fauna bears a resemblance to that of Calayan in the presence of *Cinnyris whiteheadi, Pardaliparus edithæ,* and *Sphenocercus australis,* but its *Zosterops* is not of the *meyeni* group and the new flycatcher, *Camiguinia personata,* is not represented in Calayan by any related species. The common Philippine crow, *Corone philippina,* does not occur in Camiguin.

Two species of swift, *Cypselus pacificus* (Lath.), from Batan and Camiguin and *Cypselus subfurcatus* Blyth from Camiguin are new to the list of Philippine birds. One genus and seven species are here described as new as follows:

Sphenocercus australis, Batan, Calayan, Camiguin.
Terpsiphone nigra, Batan, Y'Ami.
Camiguinia, new genus, Camiguin.
Camiguinia personata, Camiguin.
Hypsipetes camiguinensis, Camiguin.
Hyloterpe illex, Camiguin.
Zosterops batanis, Batan.
Zosterops meyleri, Camiguin.

THE BIRDS OF BATAN.

Excalfactoria lineata (Scop.).

A pair killed in a field of young sugar cane on June 5.

Sphenocercus australis sp. nov.

This species is not abundant on Batan; the few specimens obtained do not differ materially from those taken in Calayan and Camiguin. The native name is "a-ri-da-uang."

Leucotreron leclancheri (Bp.)

Not common; an adult male was taken May 31.

Columba griseigularis (Wald. and Lay.).

Large numbers of this dove are taken by means of birdlime and sold to persons visiting the island. The local name of the species is "ba-duc'." An adult example taken by us does not differ greatly from specimens from other islands. Length 17.0 inches. Base of bill, eyelids, and bare space around eyes, deep rose-pink; tip of bill very pale-yellow; irides, yellow; feet, dark-rose, leaden-gray between the scales; nails, pale-yellow.

Macropygia phæa McGregor.

A male was taken May 29. Length, 16.5 inches. Tip of bill, brown, basal part dull-red; legs, bright-rose; nails, gray; irides, double ringed, inner ring pale-blue, outer light reddish with black line between the two rings. A nest and egg were found half way up Mount Iraya on June 12. The nest was a slight platform of twigs placed ten feet from the ground in a dwarfed and twisted tree. The slightly incubated egg measured 1.45 by 1.05; it is pure white and unspotted.

Chalcophaps indica (Linn.).

I believe no specimen of this dove was killed but it was seen several times at close range.

Amaurornis olivacea (Meyen).

Two specimens taken; the species is known as "ba-hu-goc'."

Charadrius fulvus (Gm.).

Seen but once, on May 29, when an individual was flushed near the town of Basco.

Ochthodromus geoffroyi (Wagl.).

A male and a female in summer plumage were taken May 29.

Ochthodromus mongolus (Pall.).

A female in summer plumage was taken May 29.

Heteractitis brevipes (Vieill.).

An individual was seen June 14 near the town of Ibana.

Actitis hypoleucus (Linn.).

Seen in the town of Basco only.

Heteropygia acuminata (Horsf.).

A female taken May 29 had the ovaries somewhat enlarged. Bill, blackish but lighter at base; legs, dull-green; nails, black. Culmen, 0.92; wing, 5.12; tail, 2.15; tarsus, 1.12; middle toe with claw, 1.10.

Demiegretta sacra (Gm.).

A solitary bird was seen June 14 near the town of Ibana.

Butorides javanica (Horsf.).

One was seen near Ibana on June 14.

Bubulcus coromandus (Bodd.).

A small flock was noted.

Sula sula (Linn.).

Numbers observed a short distance off shore but none was killed.

Haliaëtus leucogaster (Gm.).

A few noted near the beach.

Strix candida (Tick.).

A female was taken June 2.

Alcedo bengalensis Briss.

Very rare; seen but once.

Halcyon chloris (Bodd.).

Rare, found in woods only.

Salangana whiteheadi (Grant).

A female taken June 8 was the only individual of the genus noted. This may be the recently described *Collocalia unicolor amelis*.[3]

Cypselus pacificus (Lath.).

Micropus pacificus HARTERT, Cat. Bds. Brit. Mus. (1892), **16**, 448.

When we landed at Santo Domingo de Basco, May 27, this swift was abundant, feeding low over and about buildings. The species was rarely seen again until June 2 when a few specimens were taken in the town. They usually appeared after a heavy rain, doubtless following the swarms of winged ants and termites. The mouths of specimens killed were crammed with these insects. When we climbed Mount Iraya, June 12, its summit was covered with clouds, and large flocks of swifts were feeding above the summit and at 200 to 300 feet lower.

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[3] See Oberholser, *Proc. Phil. Acad. Sci.* (1906), 193.

Cuculus canorus Linn.

A female was taken June 2. Irides, clay color with inner dark ring; eyelids, yellow; legs, nails and corners of mouth, yellow; middle toe nail dusky; bill, black above, dark-green below. Length, 11.5 inches.

Centropus carpenteri Mearns.

This species is nearly identical with *C. mindorensis.* I find no constant difference in color and the difference in size is slight and variable. It is remarkable that two species, so nearly related have such widely separated habitats.

Measurements of Centropus mindorensis and C. carpenteri.

Sex.	Locality.	Date.	Wing.	Culmen from base.	Depth of bill at front of nostril.
♂	Mindoro	Mar. 16, 1905	6.14	1.15	0.50
♂	do	Apr. 2, 1905	6.25	1.17	.46
♀	do	Nov. 22, 1902	7.28	1.22	.54
♀	do	Apr. 1, 1905	7.20	1.36	.52
♀	do	Apr. 8, 1905	6.90	1.22	.55
♂	Batan	June 7, 1907	6.68	1.28	.55
♀	do	May 30, 1907	7.26	1.40	.58
♀	do	June 1, 1907	7.48	1.32	.58
♀	do	do	7.66	1.50	.58
♀	do	do	7.25	1.36	.58

Centropus javanicus (Dumont).

A female taken May 28. Native name is "tu-la-cuc'."

Hirundo javanica Sparr.

Fairly abundant, one male taken May 29.

Hirundo striolata (Boie).

On June 14 some 100 pairs of the mosque swallow were found nesting in a wave-worn tunnel near San Carlos, Batan Island. The nests were bottle shaped and composed of mud. A few birds of this species were usually seen in company with *Cypselus pacificus.*

Terpsiphone nigra sp. nov. (Pls. I, II, and III.)

Type.—No. 6395, ♂ adult; Bureau of Science Collection; Batan Island, Batanes, Philippines; May 30, 1907; R. C. McGregor and A. Celestino collectors.

Description.—Black with a slight, purplish, blue gloss; middle of abdomen, white; under tail-coverts, black with white bases and traces of clay-brown along edges; wings and tail, black with some purplish-blue gloss on exposed margins. Irides brown; bill, legs, and wide fleshy eye-wattle, bright blue; nails, paler blue; inside of mouth, pale-green. Total length in flesh, 15.1 inches; wing, 3.58; central rectrices, 11.1; second pair of rectrices, 5.17; outermost and shortest pair of rectrices, 2.95; culmen from base, 0.75; bill from nostril, 0.50; tarsus, 0.60; middle toe with claw, 0.60; longest crest feathers about, 0.60.

The above-described specimen seems to represent the male of this species in fully adult plumage.

Nearly adult male.—No. 6411, Bureau of Science Collection; Batan Island; June 1, 1907; McGregor and Celestino.

Description.—Similar to the preceding but some feathers of lower back and a few of the inner remiges edged with chestnut; middle of lower breast, axillaries, and lining of wing, mottled with white; abdomen, white; under tail-coverts, terra-cotta-yellow with small, dusky patches. Total length in flesh, 14.8 inches; wing, 3.56; tail-feathers: longest, 10.5; second, 5.0; shortest, 3.15; culmen from base, 0.74; bill from nostril, 0.5; tarsus, 0.65; middle toe with claw, 0.65; longest crest feathers, 0.64.

Adult male first year.—No. 6372, Bureau of Science Collection; Batan Island; May 29, 1907; McGregor and Celestino collectors.

Description.—Head, neck, throat, and breast, glossy-black; mantle, back, and rump, bright-chestnut; upper tail coverts, chestnut and glossy-black (mixed plumage); lower breast, gray; abdomen, white; flanks dull chestnut; under tail-coverts, white washed with terra-cotta; alula, primaries, and primary coverts, blackish-brown; primaries and secondary coverts edged with chestnut; secondaries edged with rusty brown; rectrices, dark-brown, slightly chestnut; outer pair minutely tipped with white. Length, 7.5 inches; wing, 3.34; tail, 3.36; outermost rectrices, 2.82; culmen from base, 0.73; bill from nostril, 0.50.

Adult female.—No. 6494, Bureau of Science Collection; Batan Island; June 10, 1907; McGregor and Celestino.

Description.—Differs from the adult male, first year, in having mantle, back, tail-coverts, and secondary coverts reddish-brown instead of chestnut. Length, 7.5 inches; wing, 3.37; tail, 3.44; outermost rectrices, 2.92; culmen from base, 0.78; bill from nostril, 0.50. Another female (No. 6496) is duller, having the mantle, back, and rump decidedly grayer. Length, 7.4 inches; wing, 3.34; tail, 3.48; culmen from base, 0.66; bill from nostril, 0.46.

First plumage.—No. 6394 ♀; Bureau of Science Collection; Batan Island; May 30, 1907; McGregor and Celestino.

Description.—Above, dull-brown; top of head, back, and tail, dull reddish-brown; post ocular band dull-ocherous; chin, throat, and breast, gray, the latter crossed by an ocherous band; lower breast, abdomen, and under tail-coverts, white, slightly washed with ocherous; wings, blackish, primaries edged with dull reddish-brown; primary coverts blackish, secondaries and secondary coverts edged with dull rusty-ocherous taking the form of terminal spots on median coverts. Bill, dull-brownish; legs, pale-blue; nails, white.

Apparently this species breeds in its second year but does not reach its most perfect plumage until its fourth year.

A nest of this species found May 29 was saddled securely in a fork of a small branch. The single egg was heavily incubated. It measures 0.61 by 0.80. In color the egg is dull-white, sparsely spotted with dark umber-brown.

This species is abundant in Batan and several birds may be found in each patch of forest. A pair, or a pair and two to four young birds, may be seen feeding together. The adult male is usually fearless, often alighting within a few feet of the intruder. The flight is easy and graceful, but slow because of the long rectrices. The call is harsh and cat-like; the song is simple and of limited range, consisting of several clear notes uttered in quick succession. The native name of the species is "ti-uay-uay'."

This species seems to be closely related to *Tchitrea corvina* E. Newton from Seychelles. It also agrees with the meager description of *Callaeops periopthalmica* Grant;[4] the latter, however, has no lengthened central rectrices and the type may be a young bird.

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[4] Grant: *Bull. B. O. C.* (1895), 4, 18; *Ibis* (1895), 1, 253.

Whitehead gives the following notes on the type of *Callaeops periopthalmica* Grant:

"The unique type of this interesting Paradise Flycatcher was purchased by me in Manila. It had been shot by an Indian [Filipino] and left with the bird stuffer, unclaimed for years. I had expressed the desire to purchase this bird, but could not prevail upon the Indian to part with it, until one afternoon, much to my delight the man brought it to me, and I purchased it. The soft parts were stated by my hunter (who skinned the bird) to have been pale blue, as in *Zeocephus rufus*, which is probably quite correct. That this genus finds its nearest allies in *Arses* is, I think, open to doubt. It more resembles *Terpsiphone*, from which genus it differs in wanting a lengthened pair of center tail-feathers, which are found only on apparently very old males. * * * The crest is also like that of *Terpsiphone*, and not the short velvety-pile-like plumes of *Arses*."[5]

The man from whom Whitehead secured the type has seen our series of Batan birds and says that *Callaeops* was just like the adult male without the long central tail-feathers. He also states that the type of *Callaeops* was killed with a blow gun at Malabon, near Manila.

The facts that the type of *Callaeops periopthalmica* has remained unique and that it was killed in a region entirely unsuited to birds of this kind incline me to think that it was taken far from its normal range and that possibly it was a straggler from Batan. The identification of the Batan bird by this native as being the same species as one seen by him some ten years ago is of little value. Everything considered, to treat the Batan bird as a new species seems better than to refer it to any previously described form.

Hypsipetes batanensis Mearns.

Mearns states that in *H. batanensis* the forehead is rufescent instead of cinereous, but among 18 specimens from Batan I can detect no indication of a rufescent forehead nor can I find any other difference in plumage between them and typical *fugensis*. Birds of this genus from Batan are larger than those from Calayan and Fuga and apparently the species *H. batanensis* must stand on that character alone.

The Batan bulbul is very abundant and is known to the natives as "pi-uc'." A set of eggs, two slightly incubated and one addled, was collected May 29. The color of the eggs is pale salmon-pink obscured by longitudinal spots of umber-brown; there are also some obscure, deep, shell markings. These eggs measure: 1.21 by 0.82; 1.20 by 0.79; 1.19 by 0.81.

Another set of nearly fresh eggs was taken June 3. The shell is faintly pink and heavily spotted with rich umber brown but the spots less elongate than in first set. These eggs measure: 1.25 by 0.86; 1.29 by 0.87; 1.21 by 0.83.

Petrophila manilla Bodd.

A few seen about the town; a female was taken May 29.

Locustella ochotensis (Midd.).

This species and the *Acrocephalus* were rather abundant for a short time; specimens were taken May 29 and 31.

Locustella faciolata (Gray).

One male in adult plumage was collected May 29.

Acrocephalus orientalis (Temm. and Schl.).

Three specimens were taken May 30.

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[5] Whitehead: *Ibis* (1899), **5**, 108.

Cisticola cisticola (Temm.).

Two males from Batan, May 20 and June 14 are, I believe, of this species and the birds collected by me on Fuga and Calayan in 1903 seem to be *C. cisticola* and not *C. exilis* as recorded. This bird is fairly abundant in Batan where it is well known as "gug-nas'."

Zosterops batanis sp. nov.

Bonaparte's name *Zosterops meyeni* is based on *Dicæum flavum* of Kittlitz the locality of which is given as "Luzon." In default of a more exact locality I shall consider that specimens coming from Manila and its vicinity represent *Zosterops meyeni.*

Typical specimen.—No. 4296, ♂ adult; Bureau of Science Collection; Malate, Manila, P. I.; April 27, 1904; McGregor, Celestino, and Canton.

Description of Zosterops meyeni.—Above, including wings and tail, olive-yellow, brighter on forehead and tail-coverts; narrow ring of feathers about eye, silky-white; below this slightly dusky; lores, bright olive-yellow; chin, throat, forebreast, and under tail-coverts, bright yellow; center of breast and abdomen, faintly washed with yellow. Total length 4.0 inches: wing, 2.05; tail, 1.48; exposed culmen, 0.40; tarsus, 0.66; middle toe with claw, 0.54.

Zosterops batanis sp. nov.

No. 6357, ♂ adult; Bureau of Science Collection; Batan Island, Batanes, P. I.; May 28, 1907; McGregor and Celestino.

Specific characters.—Similar to *Zosterops meyeni* but much larger, the forehead brighter and more extensively yellow.

Description of type.—Above, yellowish-green or light olive-yellow; brighter on crown, rump, and upper tail-coverts; lores and frontal band, bright-yellow; eye surrounded by a ring of silky, white feathers, interrupted in front by a small, dusky spot; an indistinct, dusky line below eye circle; auriculars and sides of neck, light yellowish-green, like crown; chin, throat, breast, and lower tail-coverts, bright yellow, like forehead; a faint yellow wash down middle of breast and abdomen; wing-coverts, olive-yellow, like back, quills blackish and, except first primary, edged with olive-yellow; inner webs margined with white; edge of wing, light yellow; axillaries and wing lining, white, faintly washed with yellow; rectrices blackish, edged with olive-yellow. Upper mandible black, lower mandible and legs, leaden-blue; nails brown; irides, light brown. Length, 5.0 inches; wing, 2.30; tail, 1.73; exposed culmen, 0.48; tarsus, 0.72; middle toe with claw, 0.64.

Cotype.—No. 6390, ♀ adult; Bureau of Science Collection; Batan Island, Batanes, P. I.; May 30, 1907; McGregor and Celestino.

Description.—The female is similar to the male. Wing, 2.20; tail, 1.60; exposed culmen, 0.46; tarsus, 0.72; middle toe with claw, 0.61.

Measurements of five males of Zosterops batanis.

Date.	Wing.	Tail.	Exposed culmen.	Tarsus.
May 28	2.30	1.66	0.45	0.72
June 5	2.27	1.66	.46	.68
June 9	2.27	1.64	.50	.73
June 10	2.28	1.67	.49	.71
June 11	2.28	1.69	.49	.70

This species is fairly abundant in Batan Island where it is known to natives by the name "da-ti-ú."

A nest containing four fresh eggs was taken June 1. The nest, compactly made of plant fibers, was situated in the fork of a small tree; its inside diameter in 2.5 inches, inside depth 1.3. The eggs are pale blue and unmarked; they measure 0.65 by 0.48; 0.67 by 0.49; 0.69 by 0.51; 0.69 by 0.50. Two nests containing young birds were found on June 5.

Budytes leucostriatus (Hom.).

One male in yellow plumage was taken May 28. The native name of this species is "du-uad'."

Anthus rufulus Vieill.

Abundant and nesting on grassy hill sides. The native name is "bu-chi-bu-chid'."

Munia jagori Martens.

Four immature birds taken May 30 are probably of this species.

Lamprocorax panayensis (Scop.).

An immature female, killed June 3, was the only representative of the species seen.

THE BIRDS OF CAMIGUIN.

Megapodius cumingi Dillw.

One adult female was killed July 13 and a young bird was killed July 21; the latter was perched on a small limb some six feet above the ground. Fresh eggs were obtained during our stay on Camiguin.

Gallus gallus (Linn.).

One chick about five weeks of age was seen June 25 and a half-grown bird was killed July 17. The species is a common one on this island.

Sphenocercus australis sp. nov.

This species is nearly related to *S. formosæ*, but the maroon of the shoulders is continued across the back in a wide band. The entire bill is blue, the hard tip being paler while in *S. formosæ* the apical third is said to be "pale with a tinge of yellowish."

Type.—No. 6548 ♂, Bureau of Science Collection; Camiguin Island, Cagayan Province, Philippines; June 20, 1907; R. C. McGregor and A. Celestino, collectors.

Distribution.—Islands of Camiguin, Calayan, and Batan, north of Luzon.

Description of type.—General color above, olive-green; crown, ocherous-buff; forehead, lighter and more yellowish; upper mantle grayish-green; below, yellowish-green; middle of abdomen, yellowish white; flanks striped with white, pale-yellow, and dark-green; under tail-coverts, slightly washed with buff; lesser wing coverts, maroon, connected across the back by a wide and distinct band of the same color; alula and primary coverts and primaries black; secondaries black, with narrow, yellow margins; greater coverts, dark green with wider yellow margins; median coverts dark green; tail, above, olive-green, below, black with gray tips. Inner ring of iris, light-blue, outer ring pale-pink; bill blue, the hard tip paler than the base; legs and feet old rose; nails gray. Length in flesh 19.5 inches; wing, 7.60; tail, 5.40; exposed culmen, 0.82; tarsus, 1.07; middle toe with claw, 1.57.

Cotype.—No. 6633 ♀; Bureau of Science Collection; Camiguin Island, Cagayan Province, Philippines; July 5, 1907; R. C. McGregor and A. Celestino, collectors.

Description.—Similar to the male but uniform dark green above with no ocherous color on head and no maroon on wings and mantle. Length in flesh, 14 inches; wing, 7.60; tail, 5.16; exposed culmen, 0.80; tarsus, 1.04; middle toe with claw, 1.52.

The specimens from Calayan recorded as *Sphenocercus formosæ*[6] must be referred to this new species.

Leucotreron leclancheri (Bp.).

Specimens from Batan and Camiguin average larger than examples from more southern islands, but there is a great variation in series. This species was found in abundance on Camiguin. The nest is a slight platform of small twigs placed on a horizontal branch, at from six to fifteen feet from the ground. The four nests found contained but one egg each. Two eggs taken July 3 measure respectively 1.39 by 0.92 and 1.40 by 0.97. Another egg taken July 18 measures 1.24 by 0.95. These three eggs were slightly incubated. An egg in advanced stage of incubation was taken June 25.

Muscadivora nuchalis (Cab.).

The balud of Camiguin is provisionally referred to the above species.

Chalcophaps indica (Linn.).

Fairly abundant.

Hypotænidia torquata (Linn.).

Apparently rare; one individual killed.

Orthorhamphus magnirostris (Vieill.).

Two seen on the beach June 22; one male killed. Bill black, its basal skin dull-yellow; legs pale-yellow, shading into pale-lead-blue on feet; nails black. Stomach contained remains of beach crabs.

Nycticorax manillensis Vig.

A few specimens of the Manila night heron were observed on the small island opposite the town.

Butorides javanica (Horsf.).

Rare.

Dendrocygna arcuata (Horsf.).

A small flock of this species was found on the island opposite the town.

Haliaetus leucogaster (Gm.).

Rare.

Falco perigrinus Tunst.

A female in dark plumage was taken June 24. Length in flesh, 19 inches. Irides brown; bill black at tip, plumbeous at base, cere paler; nails black. One other individual was seen.

Ninox japonica (Temm. and Schl.).

Abundant and apparently breeding. Four specimens, two adults and two full-grown young, were taken June 22.

Eurystomus orientalis (Linn.).

Rare.

Halcyon coromandus (Lath.).

A female in perfect plumage was taken July 13. Irides brown; bill, legs, and nails, bright coral-red. The stomach contained a small crab.

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[6] *Bull. Philippine Mus.* (1904), 4, 9.

Halcyon chloris (Bodd.).

A young female with banded breast was taken July 6. On one occasion a kingfisher was observed to dart down and strike a half-grown chicken in the head, causing its death within half an hour.

Salangana marginata (Salvad.).

This little swift was very abundant.

Cypselus pacificus (Lath.). (Pls. IV and V, fig. 1.)

This fine bird was often seen near the beach but seldom within gunshot. A few specimens were killed.

Cypselus subfurcatus Blyth. (Pls. IV and V, fig. 2.)

Micropus subfurcatus HARTERT, Cat. Birds Brit. Mus. (1892), **16**, 457.

A male swift, taken June 26 in company with birds of the preceding species, belongs with little doubt to the above, which is new to the list of Philippine birds.

Eudynamis mindanensis (Linn.).

A male and two females were taken. Although abundant, this species was rarely seen.

Centropus viridis (Scop.).

Abundant; a very small, young bird was taken July 2.

Pitta erythrogaster Temm.

Very abundant.

Hirundo javanica Sparr.

Abundant.

Hirundo striolata (Boie).

This swallow was often seen in considerable numbers in company with *Cypselus pacificus* and I have but little doubt that it breeds on Camiguin, as specimens killed were young of the year.

Camiguinia, new genus of Muscicapidæ.

Type.—*Camiguinia personata*, sp. nov.

Generic characters.—First primary little more than half of second; fifth, longest, fourth and sixth, a trifle shorter; tail about equal to wing and slightly graduated; bill moderately flattened as in *Cyanomyias;* culmen less than tarsus and equal to middle toe with claw; rictal bristles, longer than bill from nostril; feathers of chin, lores, and forehead, short, soft, and pile like; feathers of crown, more or less scale like; occipital crest short and full.

This genus differs from *Cyanomyias* in lacking the greatly lengthened crest and the antrorse loral plumes and differs from *Hypothymis* in having the feathers of crown and crest scale-like, instead of soft and velvety.

Camiguinia personata, sp. nov.

Type.—No. 6541, ♂ adult, Bureau of Science Collection; Camiguin Island, Cagayan Province, Philippines; June 20, 1907; R. C. McGregor and A. Celestino. Length in flesh 6.1 inches; wing, 2.66; tail, 2.65; culmen from base, 0.58; bill from nostril, 0.34; tarsus, 0.65.

Description.—General color, light azure-blue; rump and upper tail coverts lighter; breast darker, frontal line, chin, lores, and a narrow, circumocular line, velvety-black, forming a mask which is narrowly bordered behind with bright, silvery, cobalt-blue, widest behind forehead and chin; middle of lower breast, abdomen, under tail coverts, wing lining, and axillaries, white; wings and tail, black, the exposed edges dark azure-blue, except first and second primaries; two outer rectrices narrowly tipped with white (in old birds only). Irides brown; the narrow eyelids light-blue; bill blue, except edges and tip which are black; legs and feet blue; nails blackish.

In a slightly immature, but fully feathered male (No. 6594, June 28, 1907) the crest is less developed, the feathers of the crown are less scale like, and the upper parts are darker blue than in the fully adult male.

Adult female.—No. 6621, Bureau of Science Collection; Camiguin Island; July 3, 1907; McGregor and Celestino.

Description.—General color, dull verditer-blue, head, neck, and sides of head brighter; forehead, dull-cobalt; chin, whitish, bordered by dull cobalt; throat, breast, and sides grayish, washed with dull azure-blue, shafts white; abdomen, flanks, under tail-coverts, and middle of lower breast, white; wings and tail, blackish-brown, edged with dull verditer-blue. Wing, 2.53; tail, 2.52; culmen from base, 0.56; bill from nostril, 0.34; tarsus, 0.66.

Young in first plumage.—No. 6566, ♀, Bureau of Science Collection; Camiguin Island; June 25, 1907; McGregor and Celestino.

Description.—Above, smoky-gray; below, white; a dusky band across fore breast; wings and tail, blackish-brown; primaries and secondaries edged with verditer; outer webs of rectrices washed with verditer.

This species is abundant in Camiguin and its habits are similar to those of *Hypothymis.* The song is extremely simple, consisting of a high note repeated six or seven times in rapid succession. The alarm note is low and harsh.

Hypsipetes camiguinensis sp. nov.

Specific characters.—Similar to *Hypsipetes fugensis* Grant and to *Hypsipetes batanensis* Mearns but larger; bill and tail longer; flanks less rufescent.

Type.—No. 6586, ♂ adult in worn plumage; Bureau of Science Collection; Camiguin Island, P. I.; June 28, 1907; R. C. McGregor and A. Celestino, collectors. Total length in flesh, 11.6 inches; wing, 5.34; tail, 4.87; culmen from base, 1.31; bill from anterior margin of nostril, 0.82; tarsus, 0.99.

Remarks.—The specimens of *Hypsipetes* obtained in Camiguin Island are in such poor condition that it is impossible to give color characters, but it is believed that adults in good plumage will be found to differ considerably from the other two species mentioned. The following table contains measurements of the three species of the genus occurring in the Babuyanes and Batanes.

Measurements of male specimens of Hypsipetes.

Species.	Locality.	Date.	Wing.	Tail.	Culmen from base.	Bill from nostril.	Tarsus.
H. fugensis	Fuga	Sept. 2	4.87	4.73	1.10	0.65	0.75
Do	do	Aug. 27	4.95	4.85	1.07	.65	.87
Do	do	Aug. 28	4.95	4.85	1.15	.72	.85
Do	do	Aug. 29	4.83	4.55	1.12	.67	.90
Do	do	Aug. 31	4.84	4.67	1.11	.68	.83
H. batanensis	Batan	May 28	5.10	4.62	1.24	.74	.88
Do	do	do	5.10	4.73	1.25	.77	.95
Do	do	do	4.90	4.57	1.28	.76	.95
Do	do	May 31	4.95	4.71	1.17	.70	.97
Do	do	June 9	5.04	4.85	1.27	.76	.95
Do	Babuyan Claro	June 18	4.90	4.67	1.22	.75	.92
Do	do	do	4.84	4.68	1.23	.75	.88
H. camiguinensis	Camiguin	June 28	5.08	5.00	1.36	.84	.91
Do	do	do	5.34	4.87	1.31	.82	.99

Cisticola cisticola (Temm.).
Fairly abundant.

Hyloterpe illex sp. nov.

Specific characters.—Similar to *H. fallax* of Calayan Island, but larger; breast and sides more strongly suffused with yellow.

Type.—No. 6573 ♂ adult; Bureau of Science Collection; Camiguin Island, P. I.; June 27, 1907; R. C. McGregor and A. Celestino. Length, 7.2 inches; wing, 3.62; tail, 2.93; exposed culmen, 0.62; tarsus, 0.92.

Remarks.—While closely related to *H. fallax* this species differs in its greater size; the greater length of wing is especially noticeable. The yellow on the breast extends forward for a greater distance than in *H. fallax.* This new species was not uncommon in the forest on Camiguin, but most of the specimens secured were in poor plumage.

Measurements of Hyloterpe fallax and H. illex, male specimens.

Species.	Locality.	Date.	Wing.	Tail.	Exposed culmen.	Tarsus.
H. fallax	Calayan	Sept. 19	3.18	2.62	0.57	0.85
Do	do	Oct. 4	3.21	2.74	.60	.86
Do	do	Oct. 6	3.25	2.80	.57	.86
Do	do	Dec. 9	3.19	2.60	.60	.83
H. illex	Camiguin	June 20	3.40	2.89	.64	.88
Do	do	June 27	3.62	2.93	.62	.92
Do	do	do	3.64	2.91	.64	.92
Do	do	June 28	3.64	2.92	.64	.90

Pardaliparus edithæ McGregor.

Fairly common. A number of specimens taken are mostly young birds. The only adult male obtained is similar to the type from Calayan.

Zosterops meyleri, sp. nov.

Specific characters.—Similar to *Zosterops aureiloris* Grant, but bill longer, forehead brighter yellow, and circle of white feathers about eye much wider.

Type.—No. 6561, ♂ in breeding plumage; Bureau of Science Collection; Camiguin Island, P. I.; June 25, 1907; R. C. McGregor and A. Celestino.

Description.—Above, bright olive-yellow, lighter on rump; forehead, golden-yellow; ear-coverts and side of neck like the back; a wide circle of short, silky, white feathers about eye, bordered below by a dusky line; lores, rich golden-yellow; below, bright-yellow; side, slightly dusky; wing, and tail, olive-green like the back. Irides, brown; bill black, but basal two-thirds of lower mandible leaden-blue; legs and nails flesh. Total length, 4.5 inches; wing, 2.10; tail, 1.57; bill from nostril, 0.32; tarsus 0.66.

Cotype.—No. 6672, ♀ adult, Bureau of Science Collection; Camiguin Island, P. I.; July 11, 1907; McGregor and Celestino. In color similar to the male. Total length, 4.3 inches; wing, 2.08; tail, 1.50; bill from nostril, 0.32; exposed culmen, 0.43; tarsus, 0.65.

Remarks.—This species belongs to the section of the genus having the lower parts all bright yellow and including *Z. aureiloris, luzonica, richmondi,* etc., but it may be recognized at once by its very wide white eye-circle. In color it is like *Z. richmondi* from Cagayancillo but it lacks the black line under eye. The species is named for Mr. John Meyler, the only American inhabitant of Camiguin Island.

Dicæum papuense (Gm.).
This species, the only representative of its family in Camiguin, was seldom observed. An adult male was taken June 27 and a young male July 8.

Cinnyris whiteheadi Grant.
Fairly abundant; specimens from Camiguin differ in no way from specimens taken in other islands.

Budytes leucostriatus (Hom.).
The only specimen seen was a male killed June 27. This individual had lost his left leg and had been unable to migrate.

Anthus rufulus Vieill.
Fairly abundant on a flat near the town.

Uroloncha everetti Tweed.
Specimens were taken June 2 and 28; abundant in the vicinity of newly planted rice fields.

Oriolus chinensis (Linn.).
Abundant.

Lamprocorax panayensis (Scop.).
A few pairs were nesting in dead trees near the town.

Y'AMI.

Y'Ami, the most northern of the Philippine Islands, is a mass of broken rock covered with a thick growth of grass, vines, and stunted, twisted trees. During half an hour spent ashore here on the morning of June 17 an immature male specimen of *Haliaetus leucogaster* (Gm.), and a male, in worn plumage, of *Zosterops batanis* McGregor were killed. In addition four species were observed of which no specimens were taken. These species are: *Halcyon chloris* (Bodd.), *Terpsiphone nigra* McGregor, *Hypsipetes batanensis* Mearns, and *Petrophila manilla* (Bodd.).

BABUYAN CLARO.

In a short time spent on the volcanic island of Babuyan Claro, June 18, specimens of *Hypsipetes batanensis* Mearns and *Salangana marginata* (Salvad.) were collected and *Cinnyris whiteheadi* Grant, *Hirundo javanica Sparrm.*, and *Corone philippina* (Bp.) were identified.

ILLUSTRATIONS.

PLATE I. *Terpsiphone nigra* sp. nov. adult male.
II. *Terpsiphone nigra,* adult female.
III. *Terpsiphone nigra,* young.
IV. Fig. 1, *Cypselus pacificus* (Lath.); fig. 2. *Cypselus subfurcatus* Blyth.
V. Fig. 1, *Cypselus pacificus* (Lath.); fig. 2. *Cypselus subfurcatus* Blyth.

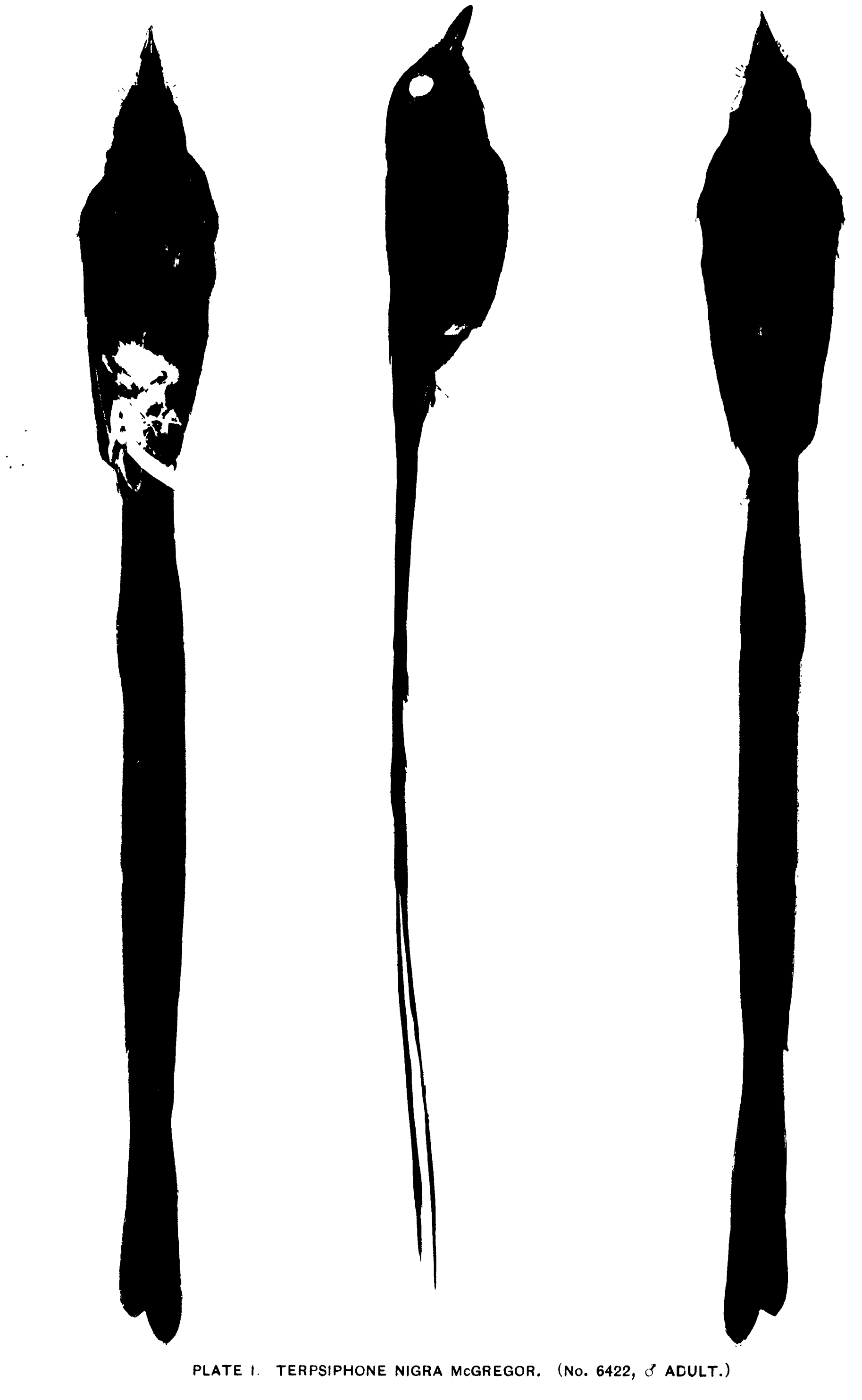

PLATE I. TERPSIPHONE NIGRA McGREGOR. (No. 6422, ♂ ADULT.)

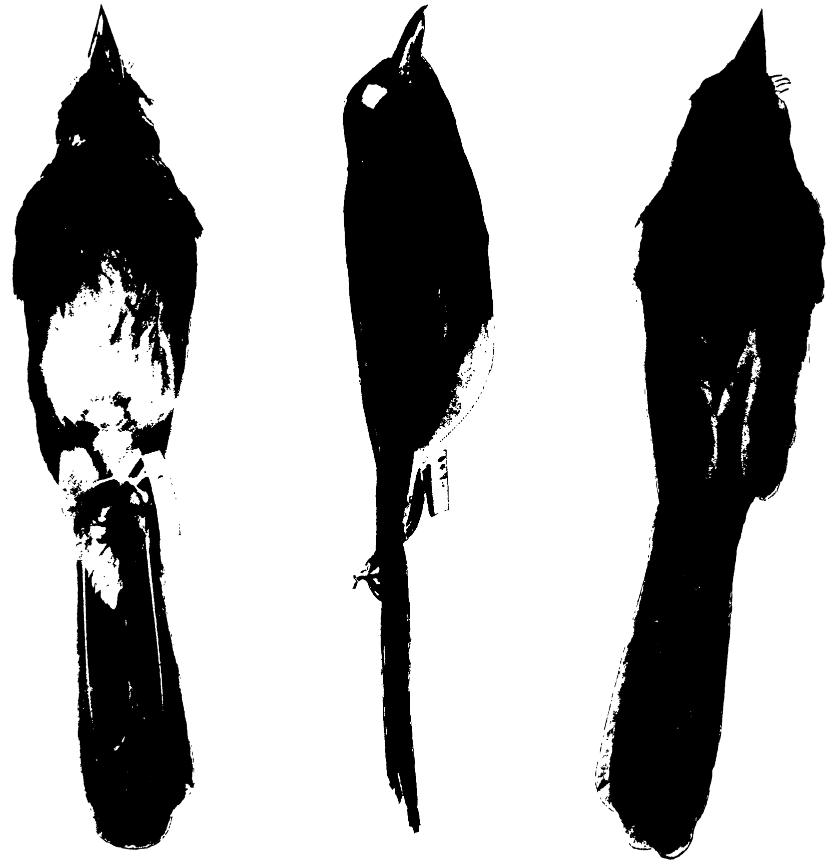

PLATE II. TERPSIPHONE NIGRA McGREGOR. (No. 6495, ♀ ADULT.)

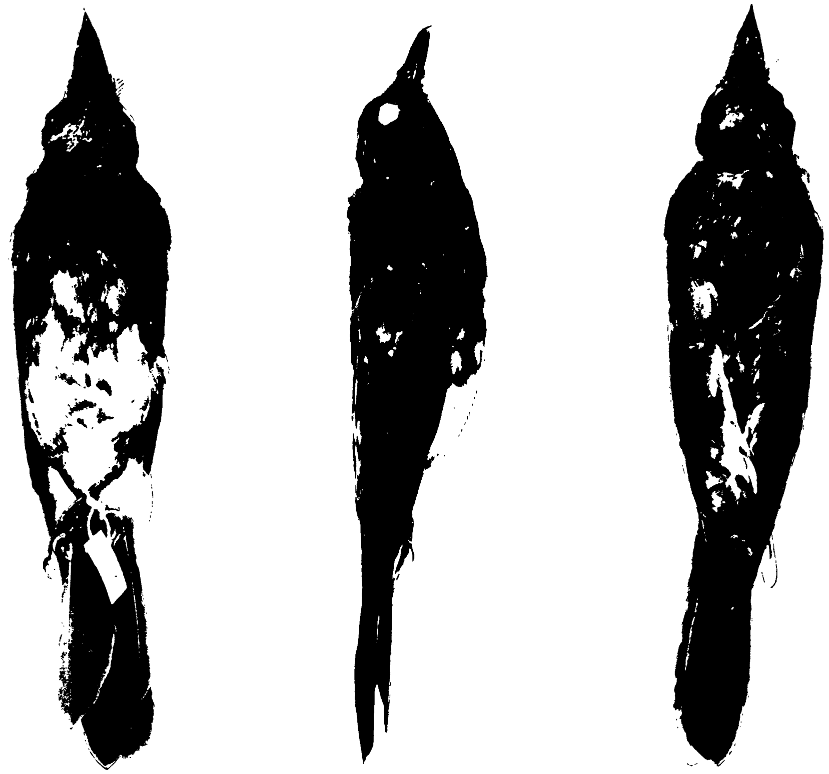

PLATE III. TERPSIPHONE NIGRA. (No. 6413, ♂ HORNOTINE.

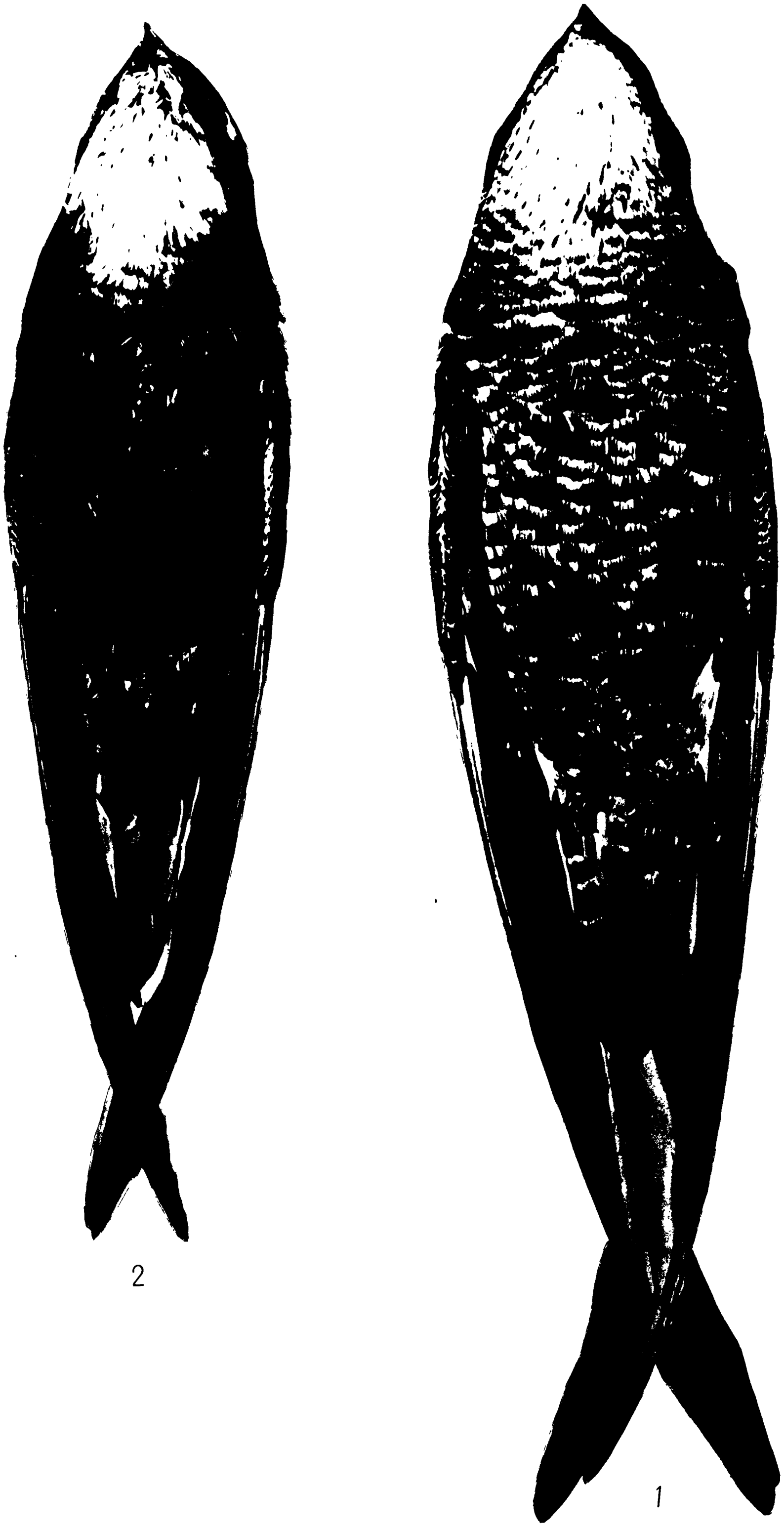

Plate IV. 1, CYPSELUS PACIFICUS; 2, C. SUBFURCATUS. (SLIGHTLY REDUCED VENTRAL VIEW.)

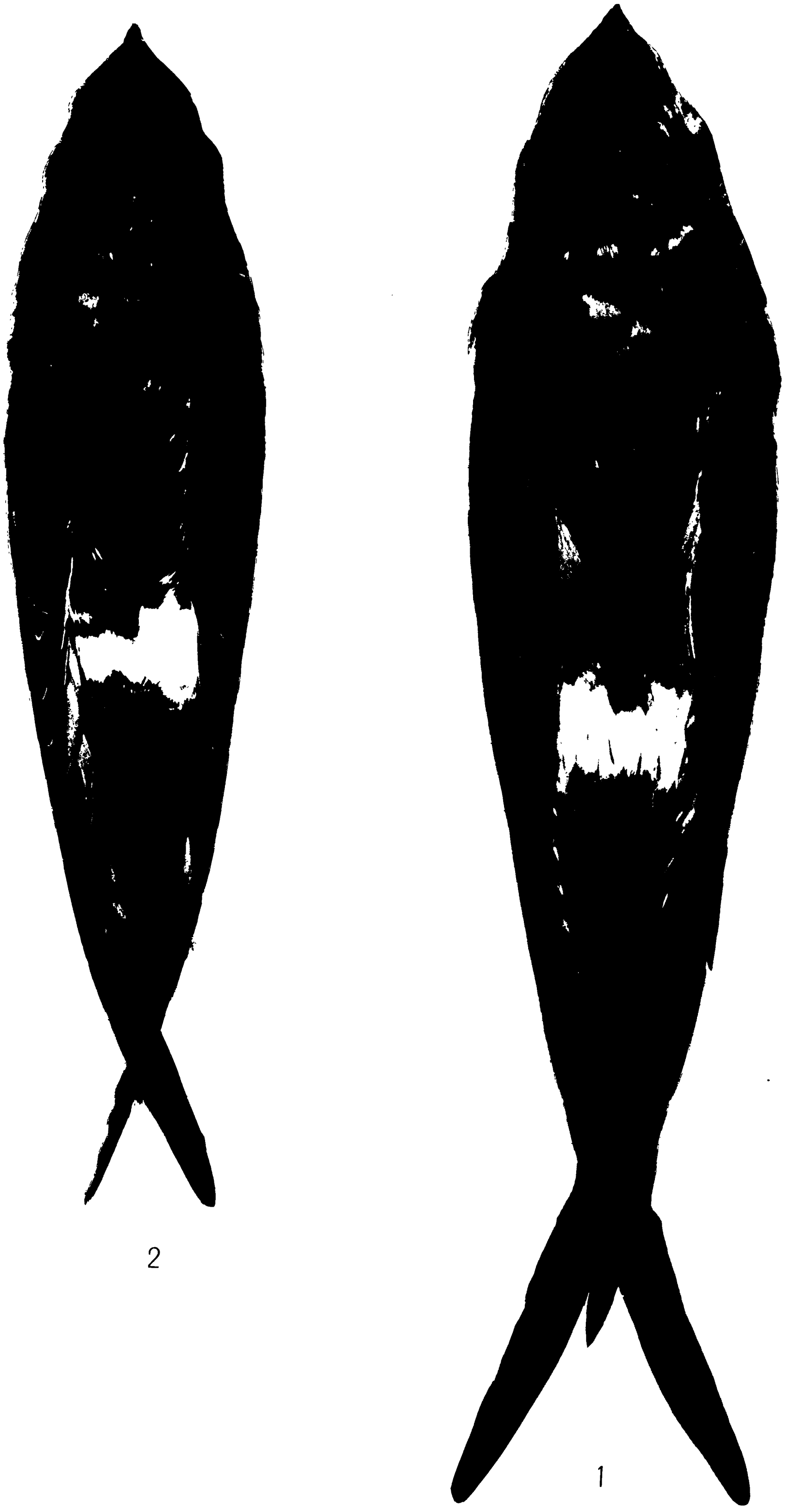

PLATE V. 1, CYPSELUS PACIFICUS; 2, C. SUBFURCATUS. (SLIGHTLY REDUCED DORSAL VIEW.)

TWO ADDITIONS TO THE AVIFAUNA OF THE PHILIPPINES.

By EDGAR A. MEARNS.
(*Major and Surgeon, U. S. Army.*)

Butorides spodiogaster (Sharpe).

On a nameless islet in Malampaya Sound off the Island of Palawan, I shot an adult female of this heron, September 12, 1906. This specimen is No. 14319 of the author's collection.

Spodiopsar cineraceus (Temminck).

At Laoag, Ilocos Norte Province, Luzon, January 25, 1907, I shot a male of the Chinese gray starling. The bird was alone and shy. The specimen is No. 14776, author's collection.

DESCRIPTIONS OF A NEW GENUS AND NINE NEW SPECIES OF PHILIPPINE BIRDS.

By Edgar A. Mearns.
(*Major and Surgeon, U. S. Army.*)

Since the publication of several papers on Philippine birds in the Proceedings of the Biological Society of Washington, in the year 1905, I have continued my explorations in the Philippine Islands, with the result that several new forms have been added to the Philippine avifauna, some of which are described in the present paper.

In identifying my birds I have had the use of the personal library of Commissioner Dean C. Worcester; and I am indebted to Dr. Paul C. Freer and Mr. Richard C. McGregor for every facility afforded by the collections and library of the Bureau of Science, in Manila. For opportunities of making expeditions in the field, I am deeply grateful to Major-General Leonard Wood and Brigadier-General Tasker H. Bliss, United States Army, under whom I have served.

All measurements given in this paper are in millimeters.

Malindangia, new genus of **Campophagidæ.**

Type.—*Malindangia mcgregori,* sp. nov.

Characters.—Wing and tail about equal; wing-feathers as in *Edoliisoma,* 3d 4th, and 5th quills longest; tail, forked, 4th quill longest, 3d subequal, outer quill shortest; webs of outer pair of rectrices sharply pointed. In form and pattern the tail resembles that of *Campochæra,* but has the webs more pointed. Bill with culmen decidedly shorter than tarsus; narrower, at gape, than length of outer toe (without claw). Stiffened shafts of rump-feathers very pronounced.

Malindangia mcgregori, sp. nov.

McGregor's cuckoo-shrike.

Type.—No. 14178, Mearns collection. Adult male from Mount Bliss, Malindang group (altitude 5,750 feet), northwestern Mindanao, Philippine Islands, May 20, 1906.

Geographical distribution.—Peaks of Mount Malindang, northwestern Mindanao, from 4,000 to 9,000 feet.

Adult male and female.—Upper parts, including crown, mantle, rump, upper tail-coverts, and middle pair of tail-feathers, uniform light gray; forehead, chin, throat, breast, and sides of head to above eyes, black; innermost secondaries, scapulars, and least wing-coverts, gray like the back; middle and greater wing-coverts, and a broad external band on innermost pair of secondaries, white; remaining wing-quills black externally, broadly white on inner webs at base; bastard wing all black; axillars and under wing-coverts white; three outer rectrices tipped with grayish-white on both webs, the innermost of the three narrowly, the next broadly, and the outermost for more than one-third of its length; chest, flanks, and thighs, gray like the back, this color fading to whitish on the abdomen and becoming pure white on the under tail-coverts. Iris, red or reddish-brown; bill all black; feet, plumbeous-black, with under side of toes yellow.

Remarks.—The black of the under side of the head extends around the neck and forms an incomplete black neck-collar which in the oldest males is but narrowly interrupted in the median line above. The sexes are colored alike; but one female (No. 14177), probably immature, has the black areas of the head and neck replaced by a dark gray color. The plumage otherwise differs from that of the adults only in having scarcely discernible fulvous edgings and wavy cross-bands to the feathers of the abdomen.

This species was abundant on Mount Malindang. Fifteen specimens were collected, ten of them males and five females.

Measurements (taken from fresh specimens by the author).—Three *adult males:* Length, 236–240; alar expanse, 335–342; wing, 110–113; tail, 108–117; culmen, 19–19.5; tarsus, 23–24; middle toe with its claw, 20–21. *Female* (No. 14177): Length, 230; alar expanse, 330; wing, 108; tail, 111; culmen, 19; tarsus, 23; middle toe with its claw, 21.

Centropus carpenteri, sp. nov.

Batan Island coucal.

Type.—No. 15190, collection of Edgar A. Mearns. Adult male. Shot by Mr. William Dorr Carpenter (for whom the species is named), in the foothills of Mount Irada, in the northern part of Batan Island, Philippine Islands, May 27, 1907.

Characters.—Similar to *Centropus mindorensis* (Steere), but larger, with less greenish reflections to the general black color.

Description of type (adult male.)—General color, black, with bluish and purplish, and some greenish luster to the metallic plumage; wings, purplish-brown. Bill, black; feet, plumbeous, claws, plumbeous-black.

Measurements.—Type (skin of adult male): Length, 440; wing, 166; tail, 278; culmen (chord), 32; depth of bill, 16; tarsus, 42; middle toe with its claw, 44.

Remarks.—This coucal is almost exactly like *Centropus mindorensis,* differing only in size and in the color of the metallic reflections to the black plumage. *Centropus mindorensis* is known only from Mindoro and the adjacent islet of Semirara. Following are its measurements, for comparison with those of *Centropus carpenteri:* Average of three adult male topotypes: Length, 398; wing, 153; tail; 238; culmen (chord) 29.2; depth of bill, 13.7; tarsus, 40; middle toe with its claw, 42.

Cyornis mindorensis sp. nov.

Mindoro red-breasted flycather.

Type.—No. 14519, Mearns collection. Adult male from the Alag River at 500 feet altitude, Mindoro, Philippine Islands, December 1, 1906.

Adult male.—Similar to *Cyornis philippinensis* Sharpe except that the blue of upper parts is slightly darked; and the under parts differ in having the abdomen and under tail-coverts orange instead of white. Specimen No. 4667, Bureau of Science collection, taken March 14, 1905, on the Rio Baco, Mindoro, by Messrs. McGregor, Celestino and Canton, has the following data written upon the label: "Bill black. Legs reddish flesh color, nails brown. Length, 5.9 inches."

Measurements (taken from skins).—Type (adult male): Length, 145; wing, 75; tail, 67; culmen, 14.5; bill from nostril, 11; tarsus, 19; middle toe with its claw, 17. Adult male No. 4667, Bureau of Science collection: Length, 135; wing, 75; tail, 65; culmen, 14; bill from nostril, 10; tarsus, 19; middle toe with claw, 17.

Remarks.—All of the series of specimens of *Cyornis philippinensis* in the collection of the Bureau of Science have the crissum white, the Mindoro form being the only one, of all the islands represented, in which this part is orange.

Rhipidura hutchinsoni, sp. nov.

Mount Malindang fan-tailed flycatcher.

Type.—No. 52, collection of Robert Schroder. Adult male from Mount Bliss, Malindang group (altitude 5,750 feet), northwestern Mindanao, Philippine Islands, June 9, 1906.

Geographic distribution.—Peaks of Mount Malindang, northwestern Mindanao, from 4,000 to 9,000 feet.

Characters.—Similar to *Rhipidura nigrocinnamomea* Hartert, but larger, without white on chest, this being replaced by deep cinnamon; and the short supraorbital white stripes unite in front, forming a band across the forehead which encroaches upon the black which edges the bill. The cinnamon color of the under parts is darker in *hutchinsoni* than in *nigrocinnamomea*. In two adult males, taken May 20, the colors of the soft parts were noted as follows: Iris, dark brown; bill, black; feet, plumbeous, with claws nearly black.

Measurements.—An adult male (No. 14166, Mearns collection), measured in the flesh, presented the following dimensions: Length, 178; alar expanse, 233; wing, 77; tail, 90; culmen, 11.5; tarsus, 20; middle toe with its claw, 14. Skin measurements of the type (adult male) are as follows: Length, 155; wing, 78; tail, 95; culmen, 11.7; tarsus, 19.5. Skin measurements of adult female (No. 14167, Mearns collection): Length, 153; wing, 73; tail, 84; culmen, 11; tarsus, 20.

Material.—Five specimens from the type locality, where the species is abundant.

Hypsipetes batanensis, sp. nov.

Batan red-eared bulbul.

Type.—No. 15199, collection of Edgar A. Mearns. Adult male from Santo Domingo de Basco, Batan Island, Philippine Islands, May 27, 1907.

Characters.—Exactly like topotypes of *Hypsipetes fugensis* Grant, but larger, and with the forehead rufescent instead of cinereous.

Measurements.—Type (skin of *adult male*): Length, 262; wing, 130; tail, 127; culmen (chord), 28; bill from anterior margin of nostril, 20; tarsus, 26; midde toe with its claw (about), 27. Average of 3 *adult males* (including the type): Length, 264; wing, 128; tail, 127; culmen (chord), 28; bill from anterior margin of nostril, 26; middle toe with its claw (about), 27. Adult female: Length, 245; wing, 116; tail, 112; culmen (chord), 25; bill from anterior margin of nostril, 17.5; tarsus, 25; middle toe with its claw (about), 25.5.

Remarks.—Following, for comparison with *Hypsipetes batanensis*, are average measurements of three adult male topotypes of typical *Hypsipetes fugensis*, taken by the author on Fuga Island, May 30, 1907: Length, 261; wing, 123; tail, 125; culmen (chord), 25.2; bill from anterior margin of nostril, 17.1; tarsus, 21.3; middle toe with its claw (about), 23.3.

Merula malindangensis, sp. nov.

Mount Malindang blackbird.

Type.—No. 14134, Mearns collection. Adult male from Mount Malindang (Lebo Peak, 5,750 feet), northwestern Mindanao, Philippine Islands, May 15, 1906.

Geographic distribution.—Peaks of Mount Malindang, northwestern Mindanao, from 5,000 to 9,000 feet.

Characters.—Largest of the Philippine species of *Merula.* Breast and under side of neck, light drab-gray, a darker shade of this color extending to the throat and chin, and forming an indistinct collar around the hind neck; middle of abdomen and crissum, nearly white, mantle, back, rump and upper tail-coverts, light sooty-brown; wings and tail dark, sooty-brown.

Adult male.—Upper side of head, mantle, back, rump and upper tail-coverts light sooty-brown; flanks slightly paler and browner; wings and tail dark sooty-brown, more fuliginous on under surface; chest and under side of neck, light drab-gray, a darker shade of this color encircling the neck and extending to the chin and throat, where the feathers have dark shaft-streaks; sides of head pale sooty-brown; feathers of the median area, from chest to crissum, with broad, white edges and a dark central area inclosing a sagitiate white spot, giving a spotted appearance to the middle of the under surface of the body; crissum with this light area expanded and practically all white; under tail-coverts sooty-brown, longitudinally striped with white or pale buff.

Adult female.—Similar to the male, but slightly smaller, and dingier in color, with a slight rufescence on sides of lower breast and flanks.

Immature male (No. 14625, Mearns collection).—Sides of lower chest and flanks more strongly washed with raw umber than in adult females; chest and throat darker.

First plumage (male, No. 14266, Mearns collection).—Upper surface, dusky, washed with raw umber, especially on the head, neck, upper back, and wing-coverts; scapulars with pale rusty shaft-streaks, and some of the lesser wing-coverts edged with the same; under surface, sepia-brown strongly mixed with reddish-brown, and spotted with brownish-black, the rufescence covering the middle of the throat and much of the chest, the blackish cordate spots being confined to the tips and the rusty bands crossing the middle of the feathers; whitish median stripe distinct, but with pale rufescent edging to the feathers except on lower abdomen; under tail-coverts, sepia-brown with rusty edging and broad, white, median stripes.

In other specimens, taken at the same season, the molt was nearly finished, leaving a few feathers with rusty bands and black spots, and with a stronger rusty washing to the flanks than in adults.

Material.—Fourteen skins from the type locality.

Merula mayonensis, sp. nov.

Mount Mayon blackbird.

Type.—No. 15272, collection of Edgar A. Mearns. Adult male from Mount Mayon at 4,000 feet, Albay Province, Luzon, Philippine Islands, June 5, 1907.

Characters.—Pattern of coloration similar to that of *Merula thomassoni* Grant, but darker, with less contrast between the coloration of the head and that of the body. Smaller, with relatively stouter bill; prænal feathers not tipped with white.

Description of type (adult male).—Upper surfaces, except head and neck, all black; under surface of body black, perceptibly washed with brown on feather edges; head and neck, very dark brown, almost black on crown; entire under surface of wings and tail, dull black; under tail-coverts, black, with narrow median white stripes, involving the shafts. Iris, very dark brown; eyelids, bill, feet, and claws, all yellow. Female exactly like the male. A yunger male than the type differs only in having the feathers of the under side of the body edged with yellowish brown.

Measurements.—Type (skin of *adult male*): Length, 215; wing, 120; tail, 101; culmen (chord, measured from true base), 22; bill from anterior margin of nostril, 13; tarsus, 34; middle toe with its claw, 32.5.

Adult female: Length, 210; wing, 117; tail, 99; culmen, 20.5; bill from nostril, 13; tarsus, 33; middle toe with its claw, 32.

Remarks.—This form is very closely related to *Merula thomassoni* Grant, from the Province of Benguet, in the highlands of Luzon, but is smaller, 8 adult male topotypes averaging: Length, 225; wing, 121; tail, 102; culmen (chord), 23.2; bill from anterior margin of nostril, 14.7; tarsus, 33; middle toe with its claw (about), 32. As lateral measurements of the bill are the same as those of *Merula thomassoni,* and the length of the latter's bill is 1.7 millimeters greater than that of *Merula mayonensis,* the bill has the appearance of being stouter. The series of topotypes of *Merula thomassoni* with which comparison has been made was taken at the same season (May 8 to June 7).

Key to the Philippine species of Merula.

[Based on adult males.]

a. Wing less than 115 millimeters; sides of lower breast and flanks chestnut. *Merula mindorensis* (Grant).

aa. Wing more than 115 millimeters; sides of lower breast and flanks not chestnut.

b. Chest, head and neck all round nearly uniform broccoli-brown (slightly darkest on crown).

c. Wing about 120 millimeters; body uniformly blackish; under tail-coverts longitudinally striped with white.

d. Larger; length, 225; wing, 121; bill from nostril, 14.7; body dark brown. *Merula thomassoni* Seebohm.

dd. Smaller; length, 215; wing, 120; bill from nostril, 13; body practically black.......... *Merula mayonensis,* new species.

cc. Wing less than 120 millimeters; body, including tail-coverts and crissum, uniformly clove-brown .... *Merula kelleri* Mearns.

bb. Chest paler, contrasting strongly with the dark color of crown.

e. Smaller (wing, 124.5 millimeters; tail, 96.5 millimeters); chin, throat and chest pale sooty-brown, rather lighter on breast, flanks, and belly; median area of under surface dark, except at vent; under tail-coverts dark brown, with pale, whitish, brown tips. *Merula nigrorum* (Grant).

ee. Larger (wing, 127 millimeters; tail, 115 millimeters); chin, throat, and chest pale drab-gray; flanks and breast similar in color to the upper surface of body; median area of under surface spotted with white anteriorly, all white posteriorly; under tail-coverts sooty-brown, with broad, longitudinal white stripes. *Merula malindangensis,* new species.

Geocichla mindanensis, sp. nov.

Mindanao ground-thrush.

Type.—No. 14264, Mearns collection. Adult female from Mount Malindang at 6,500 feet, northwestern Mindanao, Philippine Islands, June 4, 1906.

Description of type (and only specimen).—Upper surface, including head, dark, ashen-gray, closely resembling the shade of the same parts in *Geocichla cinerea* Bourns and Worcester; feathers of the back, edged with black; scapulars with black spots occupying the tip of the web on the upper side; wing and tail-feathers, shaded with brown, and crossed by obsolete, wavy bars of darker; lores, eyelids, ear-coverts, and checks, cinereous, finely mixed with pale fawn color, the malar region being cross-banded with black and fawn, and the ear-coverts longitudinally striped with white; chin and throat, white, narrowly cross-banded with black, and bordered by black stripes; pectoral region, plain cinerous-ash, with pale shafts to the feathers; lower chest and flanks, black-and-white, each feather heavily margined with jet black inclosing a sharply pointed white spot; middle of abdomen, white; crissum white, faintly washed with buff which is strongest on the lower tail-coverts; under side of wing-quills broadly white on inner border at base; edge of wing, white; axillars, white at base, broadly black at tip; under wing-coverts, black, tipped with white and pale cream color; upper wing-coverts without white spots.

Measurement of type (from skin).—Length, 230; wing, 125; tail, 78; culmen (chord), 25; bill from nostril, 19; tarsus, 32; middle toe with its claw, 30.

This species was occasionally seen as it darted through the mossy forest or alighted upon the ground; but it was so shy that only a single specimen was shot, although its loud, sweet song was frequently heard at morning and evening. It is closely related to *Geocichla andromeda* (Temminck), which Mr. Walter Goodfellow has recently (February, 1905) discovered at 8,000 feet on Mount Apo, Mindanao, as recorded by Mr. W. R. Ogilvie-Grant, in the Ibis for July, 1906, pages 468 and 477.

Zosterops halconensis, sp. nov.

Mount Halcon silver-eye.

Type.—No. 14480, Mearns collection. Adult male from Mount Halcon, Mindoro, Philippine Islands, at the altitude of 4,500 feet, November 14, 1906.

Remarks.—In the Bulletin of the British Ornithologists' Club, vol. XIV, page 13, October 30, 1903, Mr. Ernst Hartert separated the mountain *Zosterops* from Lepanto, Island of Luzon from the lowland *Zosterops meyeni* Bonaparte, under the name *Zosterops whiteheadi*, and, in the same paper (page 14) described the mountain form from 8,000 feet on Mount Apo, Mindanao, as *Zosterops whiteheadi vulcani*, observing that the form *vulcani* evidently represented *Zosterops whiteheadi whiteheadi* "on Mt. Apo, but probably older forms will also come as subspecies into this group, so that its name—that is, that of the species—may have to be altered eventually."

In addition to the forms *whiteheadi* and *vulcani*, which are represented by large series in my collections, the form here described was obtained in the Mindoro highlands.

Characters.—Sexes alike. Similar to *Zosterops vulcani*, but slightly larger. Wing, 56 against 55 millimeters; tail, 42–41; culmen 12–11.5. Color yellower, but without a longitudinal yellow stripe on middle of abdomen; sides more whitish gray; cheeks and ear-coverts paler and yellower, but the yellow confined to the chin and throat, not suffusing the upper chest; upper surfaces of a more golden green.

From *Zosterops whiteheadi* the Mindoro form is easily distinguished, when similar seasonal plumages are compared, by its greater size and more yellow coloration.

NEW LEPIDOPTERA OF THE PHILIPPINE ISLANDS.

By W. SCHULTZE.

(From the Entomological Section, Biological Laboratory, Bureau of Science, Manila, P. I.)

Since the publication of Georg Semper's famous book, "Die Schmetterlinge der Philippinischen Inseln," little work has been done on Philippine Lepidoptera, but the fact remains that our lepidopterous fauna is fairly well known. This is mostly due to the efforts of the above-mentioned author.

Most of the new species published herein are from the Lake Lanao District, Mindanao, which, up to the present, has been but little explored.

This paper contains 11 new species together with 35 species which are new to these Islands.

RHOPHALOCERA.

LYCAENIDÆ.

RATHINDA, Moore, Lep. Ceyl. (1881), 1, 99.

Rathinda cuzneri, sp. nov. (Pl. I, fig. 1.)

♀ palpi black above, second joint white below. Wings dark-brown with a bronze sheen in certain lights. Fore-wing with a large white spot on the disc. Hind-wing; an oblong spot at the upper margin and tips of tails white. Underside; fore-wing as above but somewhat lighter, a white costal streak basally, and extending across the thorax; the large, white spot extends to inner margin. Hind-wing also with a white, basal band along costal margin and a small, subtriangular, post-medial, costal spot. Large, white, triangular, discal spot; its base parallel with the inner margin. Beyond the latter and below the post-medial costal spot, another subtriangular, post-medial one. The area between and around the white spots is brown, but along the outer and inner margin, ocherish. A series of small, black, submarginal spots toward upper angle, another black spot between tails 1 and 2 and another larger one between tails 2 and 3. A white streak between the latter spot and margin. Two black bands between the large, white, discal spot and inner margin, the one next to the margin being the smaller, connected with the black spot between tails 2 and 3. All black spots and markings with metallic, blue streaks on their proximal margins. Tips of cilia and tails white.

♂: palpi white, third joint black above. Wings slightly darker than in ♀. Fore-wing with a few, light-blue scales between the discal spot and base.

Length of wing, ♂: defective.

Length of wing, ♀: 15 millimeters.

Lamao, Bataan, P. I.

Time of capture: August, 1907. (Harold Cuzner and W. Schultze, collectors.)

I take great pleasure in naming this very interesting species after Mr. Harold Cuzner who added the first specimen of this species to our collection.

Type ♂, No. 5498, and ♀, No. 7876, in Entomological collection, Bureau of Science, Manila, P. I.

HETEROCERA.

EUPTEROTIDÆ.

PSEUDOJANA, Hamps., Fauna Br. Ind., Moths (1892), **1**, 48.

Pseudojana clemensi, sp. nov. (Pl. I, fig. 2.)

Palpi dark chestnut-brown; head, on top, grey-brown; collar and prothorax black; meso- and metathorax brownish-grey. Abdomen above, reddish-ocher, each segment with a marginal, crescent-shaped, black band; below, brownish-red and without the bands. Wings brownish-grey; fore-wing darker along costal margin and with a darker, indistinct, curved, subbasal line, an indistinct ante-medial, very distinct, dark-brown, medial and post-medial lines, nearly straight. Traces of a submarginal line, angled at vein IV. Hind-wing with a straight, oblique, medial line and an indistinct, post-medial band. General color of both wings towards outer margin more reddish. Underside, dark reddish-ocher; both wings with a red-brown, medial and a very distinct, dark-brown, post-medial line, latter curved, ♀: area on both wings between medial and post-medial lines greyish and beyond the latter diffuse brown, with some greyish patches on hind-wing along outer margin. Underside paler than in ♂, but red-brown along outer margin.

Length of wing, ♂: 63 millimeters.

Length of wing, ♀: 77 millimeters.

Camp Keithley, Lake Lanao, Mindanao, P. I.

Time of capture: April, May, 1907. (Rev. Joseph Clemens, U. S. A., collector.)

Types ♂ and ♀, No. 7557 in Entomological collection, Bureau of Science, Manila, P. I.

I take pleasure in naming this species in honor of Rev. Joseph Clemens, chaplain in the Fifteenth Infantry, United States Army, who has given a large number of insects to our collection, from the very interesting Lake Lanao District.

ZYGAENIDÆ.

ZYGAENINÆ.

PSEUDEUCHROMIA, gen. nov.

♀: antennæ bipectinate; palpi short and porrect. Mid and hind tibiæ, each with one pair of terminal spurs. Wings broad, apex rounded.

Fore-wing with veins IV and V from lower angle of the cell, vein VII stalked with VIII, latter with branch, VIIIa: vein IX forming an areole with vein VIII. Hind-wing, vein V absent.

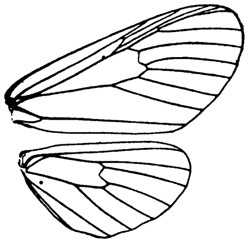

FIG. 1.

Pseudeuchromia catachroma gen. et sp. nov. (Pl. I, fig. 3.)

♀: head dark-brown; frons and collar yellow; thorax and abdomen dark-brown. A yellow spot on mesothorax, metathorax and first and second abdominal segments. Other segments with yellow, marginal bands. Legs brown with the coxæ yellow. Wings dark-brown. Fore-wing: a yellow basal, a large medial and a post-medial spot. Hind-wing with yellow basal, medial, small elongated post-medial spots; a very small marginal spot, at the inner margin near lower angle of the wing. The spots on both wings are elongated.

Length of wing, ♂: unknown.

Length of wing, ♀: 16 millimeters.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: September, 1906. (Mrs. Mary Strong Clemens, collector.)

Type ♀, No. 6264, in Entomological collection, Bureau of Science, Manila, P. I.

THYRIDIDÆ.

VERNIFILIA, gen. nov.

♀ Palpi thickly scaled; reaching above vertex of head; antennæ simple. Legs with femora and tibiæ hairy, mid tibiæ with one pair of spurs, hind one with two pairs. Fore-wing with the costa nearly straight, slightly toward apex; acute.

Outer margin below apex somewhat excised. Vein V from lower angle and veins VII, VIII, IX from close to upper angle of the cell; vein IX forked with vein X. Hind-wing, outer margin evenly rounded, veins IV, V, VI from close to lower angle and vein VII from the upper angle of the cell. Thorax and abdomen rather stout. Fig. 2.

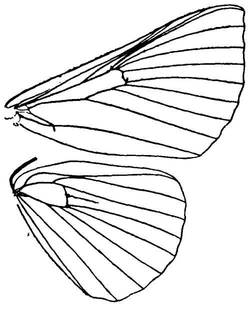

FIG. 2.

Vernifilia hyalipuncta, gen. et sp. nov. (Pl. I, fig. 4.)

♂ Head red-brown; thorax, abdomen and wings above, ocherish-red, latter somewhat lighter basally and with numerous fine dark striæ all over. Fore-wing with a row of four medial, semihyaline spots of which two are between veins I and II and the others between II–III and III–IV. The second spot from behind double. Marginal line, dark-brown, cilia grey. Hind-wing; cilia, interior half dark-brown, exterior half white. Underside of both wings darker, the striæ longer and more pronounced; traces of a medial, broad, greyish band. Fore-wing with a large, dark-brown spot just below the apex on outer margin. Abdomen below, greyish; fore femur and tibia dark-brown, others above, greyish, below ocherish. Tarsi above dark-brown; below ocherish with stripes of the same color above.

♀ with the striæ arranged in more definite lines.

Length of wing, ♂: 15 millimeters.

Length of wing, ♀: 16 millimeters.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: March and May, 1907. (Rev. Joseph Clemens, United States Army, collector.)

Types Nos., ♂ 7562, and ♀ 7380, in Entomological collection, Bureau of Science, Manila, P. I.

This new genus should be placed before Dysodia Clem., as given by Clemens and by Hampson.[1]

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[1] Dysodia, Clemens, *Pr. Ac. Nat. Sci.*, Phila. (1860), 349. Dysodia Clemens, Hampson, *Fauna Br. Ind.*, Moths (1892), **1**, 368.

NOCTUIDÆ.

GONOPTERINÆ.

CAPOTENA, Wlk., Cat. Lep. Het. Br. Mus. (1857), **11,** 714.

Capotena spatulata sp. nov. (Pl. I, fig. 5.)

Head and thorax dark-olive-brown, abdomen above, lighter; below, whitish with some ocherish scales. Anal tuft ocherish. Fore-wing greyish-brown, suffused toward inner margin. A large, dark-olive-brown, spatulate, costal spot extending posterior to disc with a darker dot in its center and surrounded by a light-grey line. This spot extends from one-fourth to three-fourths length of costal margin and three-fourths width of wing from costa toward inner margin. A wavy, submarginal, brownish line, angled between veins III and IV. Hind-wing fuscous, lighter toward base. Underside fuscous; hind-wings lighter.

Length of wing, ♂: unknown.

Length of wing, ♀: 16.5 millimeters.

MANILA, P. I.

Time of capture: 18 April, 1905. (W. Schultze, collector.)

Type ♀, No. 2755, in Entomological collection, Bureau of Science, Manila, P. I.

QUADRIFINÆ.

FODINA, Guen., Noct. (1852), **3,** 274.

Fodina lanaoensis, sp. nov. (Pl. I, fig. 6.)

Head and collar red-brown, the space between antennæ and their base whitish. Thorax chestnut-brown with a pink band and brown tuft posterior to it, another brown tuft on first abdominal segment. Abdomen and legs orange suffused with pink. Fore-wing with a small, basal, brown area along costa, the color suffusing with pinkish-grey. This area is separate from a large, irregular, dark-brown patch on basal half and along two-thirds of inner margin, by a cream-colored line which surrounds the latter except along inner margin. A broad, greyish-pink, oblique, irregular band from middle of costa to lower outer angle. Another large, dark-brown, subtriangular, apical patch also surrounded except along the costal margin by a cream-colored line. The cilia dark-greyish-pink. Hind-wing orange with the apical area fuscous-brown. Underside, orange, fuscous toward outer margin.

Length of wing, ♂: 21 millimeters.

Length wing, ♀: unknown.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: 8 April, 1907. (Rev. Joseph Clemens, United States Army, collector.)

Type ♂, No. 7359, in Entomological collection, Bureau of Science, Manila, P. I.

HYPOPYRA, Guen., Noct. (1852), **2**, 198.

Hypopyra donata, sp. nov. (Pl. I, fig. 7.)

Antennæ red-brown; head and collar light-grey-brown; palpi, toward tip, black. Thorax and abdomen light-ocher, the latter with a lateral series of black dots near anal end. Legs greyish-ocher, femoro-tibial joint of posterior legs black; spurs with black, apical bands. Wings light-ocher, irrorated with black scales. Fore-wing with very indistinct, wavy, black, basal and antemedial and with traces of a medial line on costa; three oblique lines, dentated between veins II and V, from apex to middle of inner margin. Nearly straight, light, submarginal line, with darker edges, joining the oblique lines at apex. A marginal row of light and dark dots on the veins. Cilia greyish. Hind-wing with the antemedial line straight and distinct; a slightly curved, medial zigzag line and a straight postmedial line with darker edges, from the costal margin near the apex to posterior outer angle. Three marginal dots toward anterior outer angle and two at posterior angle. Underside with more black scales than above. Fore-wing with two indistinct, black dots in the cell; distinct, curved, medial, zigzag, line; indistinct, straight, submarginal line and marginal row of dots. Hind-wing with black spot in the cell, very distinct; curved, medial, zigzag line and indistinct submarginal line; marginal row of dots as above.

Length of wing, ♂: 35 millimeters.

Length of wing, ♀: unknown.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: March, 1906. (Mrs. M. S. Clemens, collector.)

Type ♂, No. 6294, in Entomological collection, Bureau of Science, Manila, P. I.

FOCILLINÆ.

PSEUDAGLOSSA, Grote, Bull. Buffalo Soc. Nat. Sci. (1874), **2**, 47.

Pseudaglossa peregrina, sp. nov. (Pl. I, fig. 8.)

Antennæ and third joint of palpi ocher, other joints fuscous-brown, as are head, thorax, abdomen and fore-wing. Costa of fore-wing, with an ocherish streak for three-fourths of its length and around the shoulders. A black spot, with white center, at the end of the cell. Dark, wavy, postmedial and indistinct, whitish, submarginal lines. The outer area, beyond the postmedial line, slightly darker. A thin, ocherish, interrupted, marginal line; cilia alternately brown and ocher. One small, light spot near apex on costal margin. Hind-wing lighter than fore-wing, especially toward base. A darker and a lighter medial and traces of a postmedial line, near inner margin. Marginal line and cilia as on fore-wing. Below; fore-wing, light-grey, cell spot as above, traces of a postmedial line, a broad, submarginal band, darkest at costal margin and a pronounced ocherish apical spot. Hind-wing, ocherish-grey, toward outer margin fuscous. Distinct waved antemedial, medial and postmedial bands and dark marginal line.

Length of wing, ♂: unknown.

Length of wing, ♀: 14 millimeters.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: 11 May, 1907. (Rev. Joseph Clemens, United States Army, collector.)

Type ♀, No. 7556, in Entomological collection, Bureau of Science, Manila, P. I.

CATADA, Wlk., Cat. Lep. Het. Brit. Mus. (1858), **16,** 209.

Catada rubricaea, sp. nov. (Pl. I, fig. 9.)

Second joint of palpi brown with white spots, third joint and face white; face with a brown spot in center. Top of head and collar brown, outlined with white. Thorax and first abdominal segment ocher; others fuscous above, whitish below. Fore-wing reddish-ocher changing to fuscous along outer margin. A nearly straight, small, white, medial band with a thin dark-brown line, along its outer edge. Cilia fuscous with light ocherish interspaces. Hind-wing fuscous, the cilia light-ocher. Underside: fore-wing fuscous, lighter along the markin; traces of a postmedial band near costa, a few light spots along outer half of costa. Cilia as above. Hind-wing whitish with a fuscous spot at the end of cell and a wavy postmedial line.

Length of wing, ♂: 12 millimeters.

Length of wing, ♀: unknown.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: 25 March, 1907. (Rev. Joseph Clemens, United States Army, collector.)

Type ♂, No. 7387, in Entomological collection, Bureau of Science, Manila, P. I.

GEOMETRIDÆ.

BOARMIINÆ.

MEDASINA, Moore, Lep. Ceyl. (1886), **3,** 408.

Medasina nigrivincula, sp. nov. (Pl. I, fig. 10.)

General color black-brown; tips of antennæ white. Fore-wing with subcircular, antemedial, white spot in the cell, another antemedial, white spot along inner margin; two postmedial, white spots, the one in the center of the outer half of the wing being the larger, the other on inner margin. Apical spot, smaller than spot in cell. Hind-wing with broad, white, curved antemedial and postmedial bands.

♂: fore-wing; the antemedial spot at inner margin larger than in ♀ and nearly connected with the one in the cell. The medial, white band on hind wing more excised exteriorly at middle.

Length of wing, ♂: 21.5 millimeters.

Length of wing, ♀: 29 millimeters.

Camp Keithley, Lake Lanao, MINDANAO, P. I.

Time of capture: March and April, 1907. (Mrs. Mary Strong Clemens, collector.)

Types, ♂, No. 6939 and ♀, 7368, in Entomological collection, Bureau of Science, Manila, P. I.

PYRALIDÆ.

GALLERIINÆ.

ACARA, Wlk., Cat. Lep. Het. Brit. Mus. (1863), **27,** 198.

Acara strata, sp. nov. (Pl. I, fig. 11.)

Head and thorax pale-buff; metathorax white. First and second abdominal segments, above, with a velvet-like, light-brown saddle, other segments buff, with a few scattered brown scales. A large anal tuft consisting of large, triangular, greyish shiny scales. Fore-wing pale-buff, a few brown scales scattered over entire surface. A very oblique line of indistinct dots from middle of inner margin to near apex. A marginal row of brown dots midway between the veins. Hind-wing pearly-white, with brown dots as on margin of fore-wing, but only from the middle to the apex. Underside pearly-white, the costal area of fore-and hind-wings with the same color as on fore-wing above. Each wing with a darker spot in the cell, traces of a postmedial line; the row of dots along outer margin the same as above.

Length of wing, ♂: unknown.

Length of wing, ♀: 31 millimeters.

Antipolo, RIZAL, P. I.

Time of capture: 30 May, 1907. (W. Schultze, collector.)

Type ♀, No. 7520, in Entomological collection, Bureau of Science, Manila, P. I.

LIST OF SPECIES OF LEPIDOPTERA NEW TO THE PHILIPPINES.

RHOPALOCERA.

LYCAENIDÆ.

DRUPADIA, Moore, Journ., A. S. B. (1884), **53,** pt. 2, 31.

Drupadia moorei.

Sithon moorei Distant, Ann. Mag. Nat. Hist. (1882), ser. 5, **10,** 246.

Drupadia moorei Dist., Rhop. Malay. (1882–86), 236, pl. xx, figs. 20–23.

Lamao, BATAAN, P. I.

Dec., 1906, Feb., 1907. (H. Cuzner and W. Schultze, collectors.)

Nos. 6437 and 7877 in Entomological collection, Bureau of Science, Manila, P. I.

PAPILIONIDÆ.

CHILASA, Moore, Lep. Ceyl. (1881), **1,** 153.

PAPILIO, Linn., Syst. Nat. (1767), **1,** 2, 744.

Papilio (Chilasa) idaeoides.

Papilio idaeoides Hewits., Exot. Butterflies, I. Ornith. and Pap. pl. 1, fig. 2. Semper, Schm. d. Phil. **5,** 266.

Montalban, RIZAL, P. I.

10 Mar., 1906. (Charles S. Banks, collector.)

No. 5707 in Entomological collection, Bureau of Science, Manila, P. I.

This interesting species is known from Mindanao, but as Semper makes the statement that the most northerly locality where it is found is between the seventh and eighth degrees of latitude, I give the above data for one female.

Papilio brama.

Guerin, Rev. Zool. (1840), 43, taf. 1. figs. 3, 4. Dist., Rhop. Malay. 338.

Lamao, BATAAN, P. I.

Jan., 1907. (E. M. Ledyard, collector.)

No. 7700 in Entomological collection, Bureau of Science, Manila, P. I.

HETEROCERA.

SPHINGIDÆ.

OXYAMBULYX, Rothschild & Jordan, Rev. Lep. Fam. Sphing. (1903), 192.

Oxyambulyx semifervens var.

Basiana semifervens Wlk., Cat. Lep. Het. Br. M. (1864), **31,** 38.

Oxyambulyx semifervens Rothschild & Jordan, l. c. 207.

MANILA, P. I.

July, 1903. (Charles S. Banks, collector.)

No. 1332 in Entomological collection, Bureau of Science, Manila, P. I.

HIPPOTION, Hübn., Verz. Bek. Schm. (1822), 134.

Hippotion rafflesi.

Chaerocampa rafflesi Butl., Trans. Zool. Soc. Lond. (1877), **9,** 556, n. 14.

Hippotion rafflesi Rothschild & Jordan, l. c. 755.

MANILA, P. I.

3 Nov., 1904. (W. Schultze, collector.)

No. 699 in Entomological collection, Bureau of Science, Manila, P. I.

CECHENENA, Rothschild & Jordan, l. c. 799.

Cechenena helops.

Philampelus helops Wlk., Cat. Lep. Het. Br. M. (1856), **8,** 180.

Cechenena helops Rothschild & Jordan, l. c. 801.

MANILA, P. I.

5 Apr., 1906. (W. Schultze, collector.)

No. 5703 in Entomological collection, Bureau of Science, Manila, P. I.

MEGACORMA, Rothschild & Jordan, l. c. 15.

Megacorma obliqua.

Macrosila obliqua Wlk., Cat. Lep. Het. Br. M. (1856), **8,** 208.
Diludia obliqua Moore, Lep. Ceylon (1882), **2,** 4, pl. 74, fig. 2.
Megacorma obliqua Rothschild & Jordan, l. c. 15.
MANILA, P. I.
1903. (Rev. R. E. Brown, S. J., collector.)

CYPA, Walker, Cat. Lep. Het. Br. M. (1864), **31,** 41.

Cypa decolor.

Smerinthus decolor Wlk., l. c. (1856), **8,** 255.
Cypa decolor Rothschild & Jordan, l. c. 298.
MANILA, P. I.
4 Aug., 1906. (Charles S. Banks, collector.)
No. 5879 in Entomological collection, Bureau of Science, Manila, P. I.

NOTODONTIDÆ.

CERURA, Schrank, Fauna Boica (1802), **2,** 2 Abth. 155.

Cerura liturata.

Wlk., Cat. Lep. Het. Br. M. (1855), **5,** 988.
Harpyia kandyia Moore, Lep. Ceyl. **2,** 108, pl. 120, figs. *1* & 1a. larva and pupa.
Cerura liturata Hamps., Fauna Br. Ind., Moths (1892), **1,** 155.
MANILA, P. I.
Sept., 1905. (B. E. Ingersoll, collector.)
No. 4306 in Entomological collection, Bureau of Science, Manila, P. I.

LASIOCAMPIDÆ.

ESTIGENA, Moore, Lep. E. I. Co. (1859), 426.

Estigena paradalis.

Wlk., Cat. Lep. Het. Br. M. (1855), **6,** 1453.
Estigena nandina Moore, Lep. Ceyl. **2,** 149, pl. 142, figs. 1, 1a.
Estigena paradalis Hamps., Fauna Br. Ind., Moths (1892), **1,** 424.
Mount Pinatubo, ZAMBALES, 2,500 ft., and MANILA, P. I.
Apr. and July, 1907. (Charles S. Banks and W. Schultze, collectors.)
Nos. 7422 and 7708 in Entomological collection, Bureau of Science, Manila, P. I.

LYMANTRIIDÆ.

DASYCHIRA, Stephens, Ill. Brit. Ent., Haust. (1829), **2,** 58.

Dasychira thwaitesi.

Moore, Lep. Ceyl. **2,** 98, pl. 116, figs. 1, 1a (b. larva). Hamps., Fauna Br. Ind., Moths (1892), **1,** 449.
BOHOL; Camp Keithley, MINDANAO, P. I.
May, 1906; Apr., 1907. (A. Celestino and Rev. Joseph Clemens, United States Army, collectors.)
Nos. 6707 and 7404 in Entomological collection, Bureau of Science, Manila, P. I.

ARCTIIDÆ.

LITHOSIINÆ.

LITHOSIA Fabr., Ent. Syst. Suppl. (1798), 459.

Lithosia antica.

Wlk., Cat. Lep. Het. Br. M. (1854), **2**, 505. Hamps., Fauna Br. Ind., Moths (1894), **2**, 79.

Camp Keithley, MINDANAO, P. I.

Mar. and June, 1907. (Rev. Joseph Clemens, United States Army, collector.)

Nos. 7397 and 7569 in Entomological collection, Bureau of Science, Manila, P. I.

NYCTEOLINÆ.

EARIAS, Hübn., Verz. Bek. Schm. (1818), 395.

Earias chromataria.

Wlk., Cat. Lep. Het. Br. M. (1863), **27**, 204. Hamps., Fauna Br. Ind., Moths (1894), **2**, 133.

Maao, NEGROS OCC., P. I.

Feb., 1902. (Charles S. Banks, collector.)

No. 3529 in Entomological collection, Bureau of Science, Manila, P. I.

NOCTUIDÆ.

TRIFINÆ.

MAGUSA, Walker, Cat. Lep. Het. Br. M. (1857), **11**, 762.

Magusa tenebrosa.

Moore, Proc. Zool. Soc. Lond. (1867), 59.

Hamps., Fauna Br. Ind., Moths (1894), **2**, 226.

MANILA, P. I.

May, 1905. (W. Schultze, collector.)

No. 2918 in Entomological collection, Bureau of Science, Manila, P. I.

CARADRINA, Ochsenheimer, Eur. Schm. (1816), **4**, 80.

Caradrina quadripunctata.

Fabr., Syst. Ent., 594. Hamps., Fauna Br. Ind., Moths (1899), **2**, 260.

MANILA, P. I.

June, 1905. (W. Schultze, collector.)

No. 3088 in Entomological collection, Bureau of Science, Manila, P. I.

LEUCANIA, Ochsenheimer, Eur. Schm. **4**, 81.

Leucania decisissima.

Wlk., Cat. Lep. Het. Br. M. (1865), **32**, 624. Butl. Ill. Het. Br. M. **6**, pl. 109, fig. 6. Hamps., Fauna Br. Ind., Moths (1894), **2**, 269.

Camp Keithley, MINDANAO, P. I.

Sept., Oct., 1906. (Mrs. Mary S. Clemens, collector.)

No. 6940 in Entomological collection, Bureau of Science, Manila, P. I.

Leucania exempta.

Wlk., Cat. Lep. Het. Br. M. (1857), **11,** 710. Hamps., Fauna Br. Ind., Moths (1894), **2,** 273.

MANILA; Bago, NEGROS OCC., P. I.

Dec., 1905; May, 1906. (Charles S. Banks, collector.)

Nos. 4781 and 6285 in Entomological collection, Bureau of Science, Manila, P. I.

LEOCYMA, Guen., Noct. (1852), 2, 212.

Leocyma sericea.

Hamps., Ill. Het. Br. M. (1856), **9,** 92, pl. 161, fig. 7. Hamps. Fauna Br. Ind., Moths, (1894), **2,** 289.

MANILA, P. I.

Sept., 1905. (Charles S. Banks, collector.)

No. 4457 in Entomological collection, Bureau of Science, Manila, P. I.

PALINDIINÆ.

CALLYNA, Guenee, Noct. (1852), 1, 112.

Callyna costiplaga.

Moore, Lep. Ceyl. **3,** 100, pl. 156, fig. 10. Hamps., Fauna Br. Ind., Moths (1894), **2,** 357.

MANILA, P. I.

Feb., 1902. (Charles S. Banks, collector.)

No. 7685 in Entomological collection, Bureau of Science, Manila, P. I.

BAORISA, Hewitson & Moore, Descr, New Ind. Lep. from Atkinson Coll. (1879), 133.

Baorisa hieroglyphica.

Moore, l. c. 133, pl. 4, fig. 14.

Ramadasa hieroglyphica Hamps., Fauna Br. Ind., Moths (1894), **2,** 358.

MANILA, P. I.; Camp Keithley, MINDANAO, P. I.

Apr., 1906; Mar., 1907. (M. Lindquist and Rev. Joseph Clemens, United States Army, collectors.)

Nos. 6224 and 7363 in Entomological collection, Bureau of Science, Manila, P. I.

SARROTHRIPINÆ.

PLOTHEIA, Wlk., Cat. Lep. Het. Br. M. (1857), 13, 1108.

Plotheia strigifera.

Moore, Lep. Ceyl. **3,** 103, pl. 158, figs. 3, 3a. Hamps., Fauna Br. Ind., Moths (1894), **2,** 370.

MANILA, P. I.

Aug., 1905. (Charles S. Banks, collector.)

No. 3855 in Entomological collection, Bureau of Science, Manila, P. I.

STICTOPTERINÆ.

STICTOPTERA, Guenée, Noct. (1852), **3,** 51.

Stictoptera costata.

Moore, Lep. Ceyl. **3,** 123, pl. 159, fig. 8. Hamps, Fauna Br. Ind., Moths (1894), **2,** 403.

MANILA, P. I.

June, 1905. (Charles S. Bank, collector.)

No. 3181 in Entomological collection, Bureau of Science, Manila, P. I.

QUADRIFINÆ.

HYPOCALA Guenée, Noct. (1852), **3,** 73.

Hypocala deflorata.

Fabr., Ent. Syst 3, 472. Hamps., Fauna Br. Ind., Moths (1894), **2,** 453.

MANILA, P. I.

Nov., 1905. (Charles S. Banks, collector.)

No. 4676 in Entomological collection, Bureau of Science, Manila, P. I.

DELGAMMA, Moore, Lep. Ceyl. (1885), **3,** 168.

Delgamma pangonia.

Guen., Noct. **3,** 214. Hamps., Fauna Br. Ind., Moths (1894), **2,** 512.

MANILA, P. I. (Rev. R. E. Brown, S. J., collector.)

ACANTHOLIPES, Lederer, Noct. Eur. (1857), 198.

Acantholipes trajectus.

Wlk., Cat. Lep. Het. Br. M. **33,** 986. Hamps., Fauna Br. Ind., Moths (1894), **2,** 521.

MANILA, P. I.

Dec., 1905. (W. Schultze, collector.)

No. 4730 in Entomological collection, Bureau of Science, Manila, P. I.

OPHIDERES, Boisduval, Fauna Ent. Madag. (1834), 99.

Ophideres tyrannus.

Guenée, Noct. **3,** 110. Moore, Trans. Zool. Soc. Lond., **11,** 69, pl. 13, fig. 5. Hamps., Fauna Br. Ind., Moths (1894), **2,** 562.

MANILA, P. I.

Jan., 1906. (Charles S. Banks, collector.)

No. 4941 in Entomological collection, Bureau of Science, Manila, P. I.

DELTOIDINÆ.

SIMPLICIA, Guenée, Delt. et Pyr. (1854), 51.

Simplicia marginata.

Bocana marginata Moore, Descr, Lep. Atk., 195, pl. 6, fig. 19.

Simplicia marginata Hamps., Fauna Br. Ind., Moths (1895), **3,** 35.

Camp Keithley, MINDANAO, P. I.

Apr., 1907. (Rev. Joseph Clemens, United States Army, collector.)

No. 7563 in Entomological collection, Bureau of Science, Manila, P. I.

HYPENINÆ.

MARAPANA, Moore, Lep. Ceyl. (1885), **3,** 227.

Marapana pulverata.

Guenée, Noct. **3,** 351. Hamps., Fauna Br. Ind., Moths (1895), **3,** 72.
MANILA, P. I.
July, 1907. (W. Schultze, collector.)
No. 7711 in Entomological collection, Bureau of Science, Manila, P. I.

HYPENA, Schrank, Fauna Boica (1802), **2,** 2, 163.

Hypena biplagiata.

Butl., Ill., Het. **7,** 86, pl. 134, fig. 1. Hamps., Fauna Br. Ind., Moths (1895), **3,** 90.
Mailum, Bago, NEGROS OCC., P. I.
June, 1906. (Charles S. Banks, collector.)
No. 6283 in Entomological collection, Bureau of Science, Manila, P. I.

GEOMETRIDÆ.

GEOMETRINÆ.

PSEUDOTERPNA, Hübn., Verz. Bek. Schm. (1818), 284.

Pseudoterpna ruginaria.

Hypochroma ruginaria Guenée, Phal. (1857), **1,** 278.
Pseudoterpna ruginaria Hamps., Fauna Br. Ind., Moths (1895), **3,** 472.
MANILA, P. I.
1903. (Rev. R. E. Brown, S. J., collector.)

PYRALIDÆ.

GALLERIINÆ.

GALLERIA, Fabr., Ent. Syst. Suppl. (1798), 462.

Galleria mellonella.

Phalaena mellonella Linn., Syst. Nat. **10,** I, 537.
Galleria mellonella Hamps., Fauna Br. Ind., Moths (1896), **4,** 9.
MANILA, P. I.
10 Jan., 1905. (W. Schultze and R. Clute, collectors.)
No. 2199 in Entomological collection, Bureau of Science, Manila, P. I.

SCHOENOBIINÆ.

RAMILA, Moore, Proc. Zool. Soc. Lond. (1867), 667.

Ramila acciusalis.

Wlk., Cat. Lep. Het. Br. M., **19,** 977. Moore, Lep. Ceyl., **3,** pl. 184, fig. 5. Hamps., Fauna Br. Ind., Moths (1896), **4,** 42.
Mailum, Bago, NEGROS OCC., P. I.
June, 1906. (Charles S. Banks, collector.)
No. 6288 in Entomological collection, Bureau of Science, Manila, P. I.

HYDROCAMPINÆ.

TALANGA, Moore, Lep. Ceyl. (1885), **3**, 300.

Talanga sexpunctalis.

Moore, l. c. 301, pl. 181, fig. 13. Hamps., Fauna Br. Ind., Moths (1896), **4**, 221.

MANILA, P. I.

Aug., 1907. (W. Schultze, collector.)

No. 7956 in Entomological collection, Bureau of Science, Manila, P. I.

DICHOCROCIINÆ.

GONIORHYNCHUS, Hamps., Fauna Br. Ind. Moths (1896), **4**, 322.

Goniorhynchus plumbeizonalis.

Hamps., l. c. 323.

MANILA, P. I.

Aug., 1905. (W. Schultze, collector.)

No. 4164 in entomological collection, Bureau of Science, Manila, P. I.

PYRAUSTINÆ.

REHIMENA, Wlk., Cat. Lep. Het. Br. M. (1865), **34**, 1492.

Rehimena phyrnealis.

Wlk., l. c. 1859, **18**, 630. Moore, Lep. Ceyl., **3**, 290, pl. 181, fig. 5. Hamps., Fauna Br. Ind., Moths (1896), **4**, 261.

MANILA, P. I.

Jan., 1907. (W. Schultze, collector.)

No. 6509 in Entomological collection, Bureau of Science, Manila, P. I.

MEROCTENA, Led., Wien. Ent. Monatsschr. (1863), 392.

Meroctena tullalis.

Wlk., Cat. Lep. Het. Br. M., 1859, **18**, 649. Hamps., Fauna Br. Ind., Moths (1896), **4**, 376.

MANILA, P. I.

Aug., 1905. (W. Schultze, collector.)

No. 4001 in Entomological collection, Bureau of Science, Manila, P. I.

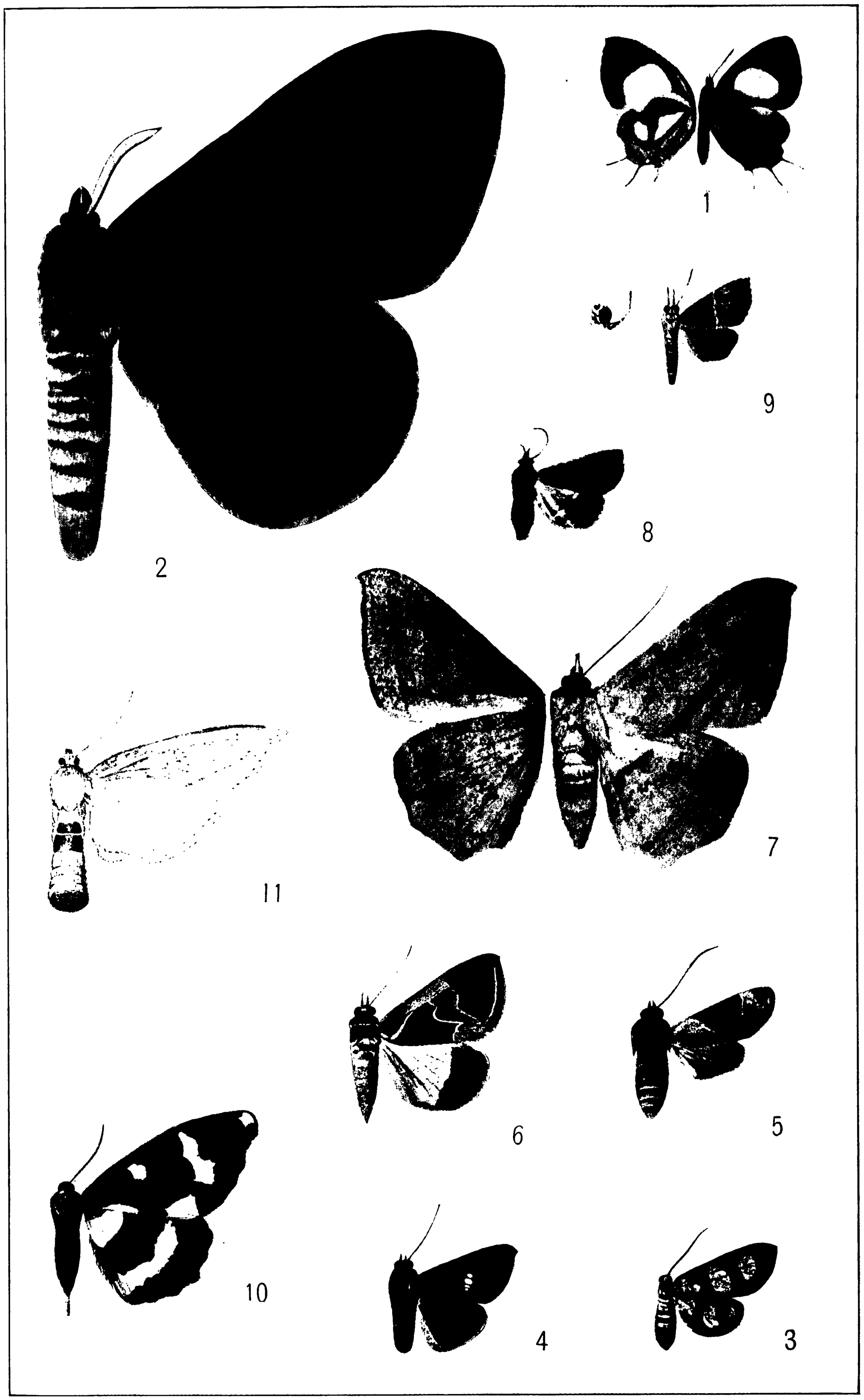

PLATE I.

THE PHILIPPINE
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THE GEOLOGY OF THE COMPOSTELA-DANAO COAL FIELD.

By WARREN D. SMITH.
(From the Division of Mines, Bureau of Science, Manila, P. I.)

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INTRODUCTION.

The Island of Cebu shows outcrops of coal in almost all portions of its area. Abella in his "Descripción de Cebú" [1] cited as many as fifteen localities scattered from one end of the island to the other, and on both coasts. Some desultory mining has been carried on near Mount Uling, in the barrios of Lutac, Alpaco and Guilaguila, but the most serious undertakings in the colliery line were the workings at Licos and Camansi in the region behind (west of) Compostela and Danao, on the east coast, about 50 kilometers north of the city of Cebu. The last active work in this field was done in 1895, for the insurrection broke out in 1896, and since the American occupation no production has been recorded, although diligent exploration and development has been resumed.

A topographic and geologic survey of the Compostela, Danao and Carmen areas was undertaken in the early part of 1906 with the intention of aiding in this work. The area which is mapped comprises approximately 100 square kilometers (36 square miles) and is indicated by the rectangular space marked on the index map. (Map I.) Messrs. Goodman and Ickis executed the topography, using transit and stadia, their work being tied to the Liloan light-house, the position of which has been closely determined by the Coast and Geodetic Survey. I was engaged in mapping the geology during the months of December, January and February; in this work I was assisted during the latter portion of the time by Mr. Goodman.

The difficulties attendant upon all tropical work have made it impossible to indicate as many details as we desired to. The two great obstacles to geologic work in Cebu are the exceptional growth of cogon grass and the very thick formation of talus. Outcrops consequently are not sufficient in frequency to allow of accurate correlation of many of the strata. If the latter were undisturbed, or even approximately so, as is the case in horizontal formations, we might infer that what we found to be true in one part of the field would hold in all parts, but in Cebu we have found such serious disturbance, the dips and strike of the beds changing so radically within only a few meters, that it would be extremely hazardous, save in a very general way, to attempt to predict the courses of these formations beneath the surface. During the progress of the mapping we found ourselves very rarely able to trace boundaries on the surface, but in time we came to judge of the underlying formation with fair accuracy by studying the topography and the character of the vegetation. All who have tried to do exploratory work through cogon grass and "ticbao" will agree that, even though the dense jungle of such districts as Batan Island is lacking in Cebu, nevertheless for certain features of the work the kind of country we have encountered in this work can be just as bad. In order to run a traverse along an arroyo, the only place where there is any hope of reaching outcrops and obtaining a key to the structure, I was forced actually to tunnel my way through the vegetation with the help of natives and bolos. This will give some idea of the difficulties we encountered. In one afternoon we covered approximately one-half mile. In a way it might appear that I owe an apology for publishing anything at all on this region at this time, but I feel that even the incomplete data which I can furnish will give information which will be of some guidance to those financially interested in the field and of interest to geologists in other lands.

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[1] Abella y Casariego, Enrique: Rápida descripción física, geológica y minera de la Isla de Cebú, Madrid (1886).

I shall refer readers of this paper to the work of Abella, cited above, for an account of the mining work done in Spanish days in this field; however, I shall exhibit one map which was made after his publication. An examination of his geologic map will show that he did not attempt to map the region in detail, so that we feel that the new one will be a distinct advance on what has already been done. I shall add no more in regard to the present state of exploration and development than that there are two companies on the ground who are making vigorous and honest efforts to ascertain the value of the properties. There are many interesting features in connection with the work which I would like to publish, but both companies in extending me many courtesies and showing me everything have requested that for the present at least this information be considered confidential. I wish to make grateful acknowledgments to the Bureau of Constabulary, which, through its two officials in Cebu and Capt. H. W. Hunt at Danao, rendered much assistance and showed our parties numerous personal courtesies; and to Mr. H. D. Everett of the Bureau of Forestry, for valuable forestry notes.

GEOGRAPHY.

GENERAL.

The area under discussion comprises a rectangular tract of about 100 square kilometers (36 square miles) of territory on the upper waters of the Cot-Cot and Danao Rivers. The eastern boundary of the district is the front, or coast, range of hills which includes Mounts Licos and Mangilao; the western is formed by the Cordillera Central, which is the long, sinuous backbone of the island. The area extends as far north as a line east and west from the *pueblo* of Cármen, while Mount Acsubing marks its southernmost extension.

CLIMATE.

The monsoons are not as clearly marked in Cebu as, for instance, they are in Luzon. This is largely due to the fact that the mountains are not so high, nor is the width of the island sufficiently great to make conditions on one coast appreciably different from those on the other.

Tables are given below showing the monthly record of rainfall and temperature. Rainfall is not always a vital point for consideration in many temperate regions, but in the tropics, where the precipitation takes such a prominent place at certain periods of the year and at times causes such destruction, before constructing important engineering works it is absolutely necessary to know the amount of rainfall and whether it is apt to be concentrated.

TABLE I.—*Temperature and rainfall in Cebu during the year 1904.*

[Philippine Weather Bureau.]

Month.	Temperature.	Rainfall.[a]	Number of days.	Maximum in one day.
	°C.	mm.		mm.
January	25.8	327.5	23	[b] 180.8
February	25.7	48.5	11	20.6
March	26.7	78	9	40.4
April	27.1	145.2	13	63.8
May	27.6	158.6	13	40
June	27.2	178.1	15	48.3
July	27.4	92.8	6	63
August	27.2	156.4	17	36.1
September	26.5	116.1	16	24.9
October	26.4	145.1	20	25.6
November	26.1	149.1	10	50.3
December	25.8	50.7	12	15.5

[a] Total for the twelve months, 1,646.1 millimeters, or 64.81 inches.
[b] Or 7.12 inches.

TABLE II.—*Temperature and rainfall in Cebu during the year 1906.*

[Philippine Weather Bureau.]

Month.	Temperature.			Rainfall.[a]
	Mean.	Maximum.	Minimum.	
	°C.	°C.	°C.	mm.
January	26.4	31.2	19.5	59.5
February	26.5	31.4	21	33.9
March	27.2	31.9	20.6	35.8
April	28.1	32.1	22.8	18.6
May	28.5	33.9	23.4	94.3
June	27.5	32.5	22.8	219.8
July	27.3	32.5	21.5	128.1
August	27.7	32.5	23	94.6
September	27.1	32.5	22.4	191.9
October	27.1	32.4	22.8	223.4
November	26.5	31.5	20.5	175
December	26.9	30.9	21.9	98.6

[a] Total for the twelve months, 1,373.5 millimeters, or 54.07 inches.

An inspection of this table will show that there are no sharply defined dry and rainy seasons. The heavy precipitation of January might in another year come in the month of May. The rainfall in Cebu, where the relief is pronounced and trees over much of the area conspicously lacking, gathers very quickly in the arroyos and in a very short time the streams attain alarming proportions and work great havoc.

VEGETATION.

I am very fortunate in being able to make use of the excellent report of Forester H. D. Everett, of the Bureau of Forestry. His report is much more reliable and complete than any discussion I could give and therefore I have abstracted it almost in its entirety and in his own words:

> Less than fifty years ago most of this hill and mountain country was covered with a good, merchantable forest, but clearing has been so rapid that now only an inferior forest remains, small in area and located on the steepest and most inaccessible slopes and peaks. The forest areas are as follows, in order from the poorest to best: On the mountains of Licos, Manghilao, Pulgason, Lantauan, Donga and Uguis. Licos and Pulgason are near the mines of the Insular Coal Company, but the others are nearer and more accessible to the mines of J. G. White & Co. On the west side of the main divide of the island and tributary to the Balamban River are the forests of Sacsac, large in area and in good condition, but practically inaccessible from the east.
>
> *The forest of Mount Licos.*—Mount Licos is a long, narrow ridge extending from Camansi to the Compostela mines, reaching a height of 1,750 feet above the sea. Only its top and steepest rocky slopes, which can scarcely be climbed, have any tree growth and this is small and scattered. It is mapped as noncommercial. Almost no trees of the better species grow there, although twenty years ago a considerable quantity of good timber was secured in this place. Almost no timber can be obtained for the mines. A few pieces for temporary work of inferior kinds can possibly be cut.
>
> Although this forest is small and in a deplorable condition, if it were protected from cutting and *caiñgins* (forest clearings) for some years, it would probably recover. The land is only fit for forest use.
>
> *The forest of Mount Pulgason.*—Mount Pulgason is a large mountain with many radiating ridges most of which are covered with cogon or small brush. Many *caiñgins* cultivated to corn are on its slopes. The forest is located on the top and in some of the draws near the top, on both the east and west sides. Some of this may be considered as merchantable, although it has been cut over for many years by the licensee, Ambrosio Lao. It is evidently by his efforts that so much of this forest has been preserved from destruction by *caiñgins*, since the slopes are not very rocky and *caiñgins* could easily be made.
>
> The forests have a denser stand, larger trees and better species than on Mount Licos, yet nevertheless they are in a poor condition, being characterized by small trees and scattered growth. The species are mostly unknown small trees

with aluan,[2] sambulauan, and a little narra and amaga. The narra and amaga are small trees and scarce.

The forest of Mount Manghilao.—Mount Manghilao is part of the coast range of hills and lies close to the towns of Danao and Carmen, showing prominently. Its elevation is about 2,250 feet above the sea. The remaining forest rests on the rockiest part of the top and partly down the rocky slopes, which in places are cliffs. The forest has been subjected to excessive cutting in the past and to considerable destruction by *caiñgins*. It is a tangle of vines, saplings and small trees with a few scattered large trees of lauan, manaog, nipot-nipot and nato. There are present, as in all of these mountains, a large number of tree species, few of which are valuable. A part of this forest may be called merchantable here, although in better timbered regions it would be nonmerchantable. First-group trees are practically wanting. What is really called for in this forest is absolute protection for many years.

The forest of Mount Lantauan.—This mountain is a sharp peak of volcanic rock, so rocky and precipitous that some good timber still remains because it is so difficult to cut. In places the forest is fairly dense and of good sized trees, chief among which are white lauan, duca, nato, maobog, lanete, narra, bagtican and ditaa. On this mountain considerable mine timber can be cut without serious silvicultural damage to the forest.

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[2] List of tree species with native and botanical names mentioned in Mr. Everett's report:

Agusahis =*Ficus* sp.
Amaga =*Diospyros* sp.
Amahuyan =*Dysoxylum* sp.
Bagtican =*Shorea* sp.
Betis =*Illipe betis* (Blco.) Merr.
Bogo =*Garuga floribunda* Dcne.
Camungayon =*Aglaia* sp. ?
Datilis or caballero =here refers to *Leucœna glauca* Benth.
Ditaa or dita =*Alstonia scholaris* R. Br.
Duca =*Cynometra* sp.
Duñgon (bayog) =*Tarrietia sylvatica* Merr. or *Pterospermum* sp.
Dungula =*Vitex aherniana* Merr.
Guijo =*Shorea guiso* Bl.
Hambabæ =*Nauclea* sp. or *Randia* sp.
Lanete =*Wrightia* sp.
Lauan =*Shorea* sp.
Manaog (balacbacan) =*Shorea* sp.
Mata-mata =*Aglaia* sp.
Moabog =?
Molave =*Vitex* sp.
Nancaon =?
Narra =*Pterocarpus* sp.
Nato =*Palaqium* sp.
Nipot-nipot =*Gleditsia rolfei* Vid. ?
Pagolingan =*Cratoxylon floribundus* F. Vill.
Pagsagon =*Mimusops elengi* L.
Pili =*Canarium* sp.
Putian =*Aglaia* sp.
Quia-quia =?
Sambulauan (amuguis) =*Koordersiodendron pinnatum* (Blco.) Merr.
Taguilumboy =*Eugenia* sp. or *Cynometra* sp.
Tindalo =*Pahudia rhomboidea* Prain.
Tunguatingan =*Nauclea* sp.
White lauan =*Shorea* sp.
Yacal =*Hopea* sp.

The forest of Mounts Uguis and Donga.—Mount Donga is really a foothill of the higher mountain or ridge called Uguis. The upper slopes and tops of these mountains are fairly well wooded and have suffered less from cutting than the other mountains. This is due to the fact that they are farther from Danao and that their steep slopes, covered with huge volcanic bowlders, make logging extremely difficult and in places impossible. However, mine timbers could be cut on these slopes and skidded out by hand at a considerable expense. It is probable that timber could be imported from other islands at less expense than it could be secured on this mountain, except in famine years when the people work very cheaply.

Uguis and Donga have a fair sprinkling of narra, bagtican, amaga, lanete and duñgon among the many inferior species which are also present.

The forest of the Sacsac River.—An extensive virgin forest exists across the main divide of the island and tributary to the Balamban River, containing large trees of lauan, sambulauan, quia-quia, narra, pili, bagtican and other timber species. Bejuco (rattan) also grows in this forest in fair abundance. At present the forest is inaccessible from the east, but it is barely possible that at great expense, yet not a prohibitive one, a road could be made up the Uguis stream and across the divide by which this timber could be brought to the Danao River and thus to the mines.

Cutting rules, copies of which have been sent to the three licensees, are based on the following facts and conclusions:

(1) In these forests it is possible to secure only a small part of the necessary mine timber from first-group trees.

(2) There are some species of the lower groups which will serve fairly well, especially for temporary work.

(3) The cutting of small trees of the first and second groups in these forests will exterminate those species.

(4) It will be necessary to import timber from other regions for the proper, future development of the mines.

(5) The future development of the mines will double the demand for timber.

(6) The trees at present being cut are small with an average diameter of not more than 25 centimeters.

(7) The forests, especially those of Licos, Pulgason and Manghilao, are in very poor condition.

Use of timber in the coal mines.—Timber was used in former times and is needed at present in the form of ties for the tramway leading from Camansi to Danao and as posts, caps and lagging for the tunnels. The company which operated the mines in Spanish times used mostly the most durable timber of the first group such as molave and tindalo, both for the tramway and for the tunnels.

Old timbers of the Compostela mines.—Most of the timbers were placed in these mines in the years 1895 and 1896. They consist for the greater part of molave, tindalo, yacal and narra, with a few of the inferior or little known species which grow in the neighborhood. The lagging was made of poles of datilis or caballero. Some of the old tunnels are now being cleared out and new timbers put in where the old ones are no longer serviceable. Up to the present time not more than 40 per cent of the old posts and caps have been removed in the Enrique Abella tunnel. Many of the molave timbers are perfectly sound after about twelve years of service. The following specimen sections were taken from some of the old timbers at the ends where they were in contact with the soil.

No. 1.—Pagsagon post, sound with the exception of about one centimeter on the outside and one bad knot which had weakened the post.

No. 2.—Betis (?) post, in good condition.

No. 3.—Guijo cap, badly rotted at the ends.

No. 4.—Pagsagon post, fairly sound but weakened.

No. 5.—Tindalo post, affected in spots but fairly sound.

No. 6.—Bogo post, affected in spots so as to be useless.

No. 7.—Molave post, slightly affected so as to be weakened.

No 8.—Molave cap, fairly sound with hollow at the heart which was probably there originally.

No. 9.—Tindalo cap, still useful.

No. 10.—Nipot-nipot cap, badly rotted.

No. 11.—Putian (?) post, slightly affected at heart.

No. 12.—Taguilumboy post, still fairly sound and could serve for some time longer.

No. 13.—Nancaon post, in fair condition.

The above timbers have seen ten to twelve years' service. In general, the caps are affected by decay sooner than the posts.

A large proportion of the inferior or little known woods of the locality were used in the Camansi mines. Some of them have proved to be very durable, almost as much so for the purpose as molave. These are most notably taguilumboy and hambabæ. Putian, camungayon, nancaon, mata-mata, tunguatingan, and amahuyan have shown themselves to be fairly satisfactory.

The conditions affecting the durability of the mine timbers are different from those influencing an *harigue* (house post) or other timber exposed to light and air; they are in almost complete darkness, are constantly dripping with moisture and are covered with slime. The air inside the tunnels is heavy, hot, laden with moisture and it varies but little in temperature. The white ant is said not to work, except at the entrance to the tunnels, and no injurious work of insects was observed in the old timbers. Consequently, conditions are not such as to cause the most rapid decay, although favorable to the growth of destructive fungi.

Present use of timber.—The wood used in the mines is in the form of posts, caps and lagging. For 100 meters of tunnel 170 caps, about 7,000 short stakes for lagging and 340 posts are used, having an approximate volume for posts and caps of about 20 cubic meters. The lagging used is formed of the small stems of the datilis or caballero, a brushwood growing in thickets near streams, which does not make a timber tree.

The caps are about 1.35 meters in length and 0.50 in circumference; the posts about 2.35 by 0.55 meters. They are entire, round logs, cut from small trees and are not treated in any way to preserve them from decay. A coal-mining operation on a fairly large scale would run about 1,500 meters of tunnels a year, which would require about 300 meters of timber for posts and caps, exclusive of that used for the tramway and for general construction. This would mean about 2,000 small trees to be cut to about the size now being used.

Since work is now progressing only on a small scale, old tunnels being cleared and a few new ones started, at present but a small amount of timber is required. This demand can be supplied for a time by the neighboring forests, but as soon as the operations are greatly extended it will be necessary to secure material from other sources.

Possible sources.—It is probable that rejected railroad ties can be obtained which should make good mining timbers. The dungula growing on the tract of the Insular Lumber Company should be a most excellent mine timber. This is now being cut and doubtless, from time to time, a steamer load could be secured. The better forested islands, such as Mindanao, Samar, Paragua, and Mindoro, should be a source for mine timbers of the first group. Only further experience and observation will show how durable for the mines are the many, little known timbers of the Islands. Some of these will undoubtedly prove to be very satisfactory.

It is probable that in time it will be practicable and advisable to treat mine timbers with preservatives, in this way using the most abundant and cheaper kinds. Painting timber with the preservative or giving the timber an open bath treatment will be found the cheapest methods. In this connection, attention is called to Press Bulletin No. 141, November 27, 1906, United States Forest Service, "Prolonging the Life of Mine Props."

POPULATION MARCH 1, 1907.

The Filipinos inhabiting this island are called Visayans and are, save for minor differences in dialect, the same as the people of Leyte, Negros and Panay.

As I have pointed out in my previous paper,[3] the greater part of the population and also that portion which belongs to the better educated class, is confined to the narrow coastal tract in the towns of Carmen, Danao and Liloan, and others and to their outlying barrios. The dwellers in the hill country are extremely poor, when their state is compared with our manner of living or even the mode of life of the people of the coastal plain. Corn is their chief staple. I believe this dominant corn diet is peculiar to the *Cebuanos*. The *ilustrados* largely control the fertile cove areas in the intermontane tracts.

The peasant of Cebu is very superstitious. As an instance of his ignorance and credulity I may cite one rather remarkable case, which, however, at one time came very near to not having an amusing aspect. In our trips here and there over the field we were obliged to pass by many native houses and near the end of the work we were surprised to find the children all running away from us, or their mothers would quickly hide them as soon as we came in sight, a thing which had never been done in this district on previous visits. This continued for some time, with also an increasing surliness on the part of the men. Finally, an engineer of one of the coal development companies was stopped late in the evening when he was some distance from camp. The natives proved themselves to be in a hostile mood and as they had *bolos* (long knives) and one or two spears he felt warranted in drawing his side arm to protect himself and not until the *teniente* of the local *barrio* appeared and explained in Spanish, did he learn the cause of their attitude. It seems that some malicious person or persons had played upon the credulity of the people, making them believe that the Americans were stealing the children in order to kill them and let their blood drop on the ground, this being a supposed means of ascertaining where the coal was. It took some days to eradicate this belief from the minds of the peasants and for a time it kept the local Constabulary force doing guard over the several camps. This is the only incident of the kind which has ever been brought to my attention in the Philippines and I consider it altogether exceptional.

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[3] "Contributions to the Physiography of the Philippine Islands: I. Cebu Islands." *This Journal* (1906), 1, 1043.

HYDROLOGY.

The area under consideration is well drained by two fair-sized streams, the Danao and the Cot-Cot Rivers, which become raging torrents in rainy weather, but quickly subside, and in the dry season are so shallow that not even the smallest *bancas* can navigate them. The generally deforested condition of the region is responsible for this condition.

TOPOGRAPHY AND PHYSIOGRAPHY.

The general appearance of this country is mountainous although in reality the highest point, apart from the *Cordillera Central* is not over 685 meters (2,245 feet). The reason for the exaggerated topography is the pronounced relief which is due to two main causes, first, the folded and warped condition of the rocks, and second, the absence of forest, which gives the meteoric waters a free field to do their work of dissection. The absence of forest is also a factor in making visible at a glance even the minutest topographic features, whereas in countries with a heavy forest mantle much of the relief would not be seen.

The topographic features of this region are as follows: 1. The quite complete dissection of the country. 2. The long, limestone-capped ridges of Mounts Licos, Manghilao and Lantauan. 3. The rather unconventional orientation of the drainage. 4. The change of topography with change of formation.

In a previous paper,[4] I have spoken of the intermediate uplands of this island. They comprise all of the elevated tract between the coastal plain, with the low coast hills, and the *Cordillera.* They are largely underlaid by limestone. Corn is the principal product. The people, while apparently very poor, nevertheless are satisfied and have all they need. They form the most peaceable portion, by far, of the native population.

In the terms of the modern science of physiography this region is in maturity, namely, it is in such a condition that a little less denudation or a little more would decrease the relief and make all the outlines less pronounced. Further denudation, unaccompanied by elevation or warping, would cause the region to pass into "old age."

The most striking topographic features are the limestone-capped ridges of Licos, Lantauan, and Manghilao. The limestone being more resistant than the underlying shales and soft sandstone, has protected certain areas between the master streams and hence the highest points are of the former material. This limestone does not conform to the beds below, but lies as a mantle upon the folded and truncated coal measure beds, and in some cases upon igneous formations. However, there is a decidedly warped appearance to this formation which is in part due to the configuration of the older topography upon which the limestone was laid down, and also to some minor folding subsequent to its deposition.

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[4] *Loc. cit.,* 1043.

A somewhat noteworthy feature of the drainage is the orientation of the Cot-Cot and its tributaries, the Jimarco, the Parel and the Muao; and the peculiar course of the Danao.

The Cot-Cot and its three tributaries are seen to conform with reasonable closeness to two lines which make an angle of 92° with one another. The Jimarco and the Cot-Cot fall on a line the course of which is N. 37° W., while the Muao and the Parel come into the main stream approximately at right angles or along a line N. 55° E. I am strongly of the opinion that the N. 37° W. line is a fault line, although I have no other cause to think so than its great persistence.

Side branches under normal conditions do not join the trunk stream at right angles, but always in such a manner as to make an acute angle upstream with it. The reason for this departure in this region lies in the structure of the underlying formations. In a traverse of the Muao, in more than one place, I found that the strike of the beds conformed to the direction of the stream and there should be little doubt but that this factor has controlled its course, as it would be much easier for the stream to cut along this line than across the formations. As the dip is generally to the southeast throughout the greater part of this region, it would be expected that the stream would shift laterally and in the direction of the dip.

I am not so certain that this holds true in the case of the Taganejan, as exposures of the sedimentaries are not so plentiful. If we now examine the course of the Danao, the headwater tributaries of which are known as the Cajumayjumayan and the Donga we see that it starts on the northeast slope of Mount Lantauan and flows southwest in the Cajumayjumayan basin until it strikes the *Cordillera,* it then swings to the south at the base of this ridge and turns rather sharply to the southeast, worming its way in great curves through a cañon-like cut in the basal igneous formation, and still farther down it takes a due easterly course to the sea.

As the Cajumayjumayan Valley is a syncline, the river in this part of the course is a consequent stream. In time the courses of Donga and Cajumayjumayan Creeks will coincide, as both shift laterally along the dip. That part of the stream which lies between Sibacan and Ustaganon Creeks is antecedent. Its present incised meanders in that portion are evidently inherited from an earlier and higher stage of the stream, and may point to a post-Miocene peneplain.

I found that the courses of the Mantija and Mangliji side streams were almost entirely controlled by structural conditions. As can be seen by a cross section of almost any part of the field, the coal measures are folded to a considerable degree in some places. The Magliji is located on the crest of a small local anticline and the reason for this position is that there is usually along the crest of an anticline a fracture system which would give a stream a foothold.

It would be interesting to know to what extent jointing and faulting had affected the orientation of drainage in this area, but unfortunately there are few good exposures, and quarries and mining operations have not yet proceeded far enough to throw much light on the underground condition.

To one accustomed to read topographic features much of the underlying structure and formations of a country is revealed, whereas to another person a surface examination would disclose nothing. For instance, the abrupt change in the contours at the point where the Ustaganon comes into the Danao should be noted; west of that point the rock is igneous, a hard, fairly structureless diorite, east of that point to a place as far as the end of the railroad, the contours are fewer and farther apart, showing gentle slopes and outlines, the underlying formation is that of the coal measures, consisting largely of soft shales. Again, the crowded contours just south of the end of the railroad track at Camansi should be considered. They mark a great, white cliff of limestone, which usually gives this character to the topography. I may state that such topography is not very favorable to engineering projects.

GEOLOGY: GENERAL.

For purposes of convenience, and also because of a natural distinction between the areas, I shall treat the geology of this region under the following heads:

1. The Acsubing-Muao region.
2. The Mount Licos region.
3. The Cajumayjumayan region.
4. The Sili Creek region.

THE ACSUBING-MUAO REGION.

This portion of the district, lying south of the Cot-Cot River, is largely covered by a sheet of andesite and it therefore is much more simple to deal with. Although this part of the area was evidently entirely covered by this sheet of andesite, the streams have greatly dissected it, cutting down through it for over 200 meters (nearly 700 feet) to the unconformable coal series below. Isolated residual patches of the upper limestone are scattered at long intervals, resting upon the andesite.

The streams are naturally for the greater part deeply incised with V-shaped cross sections as a result of the character of the formation which is predominantly igneous.

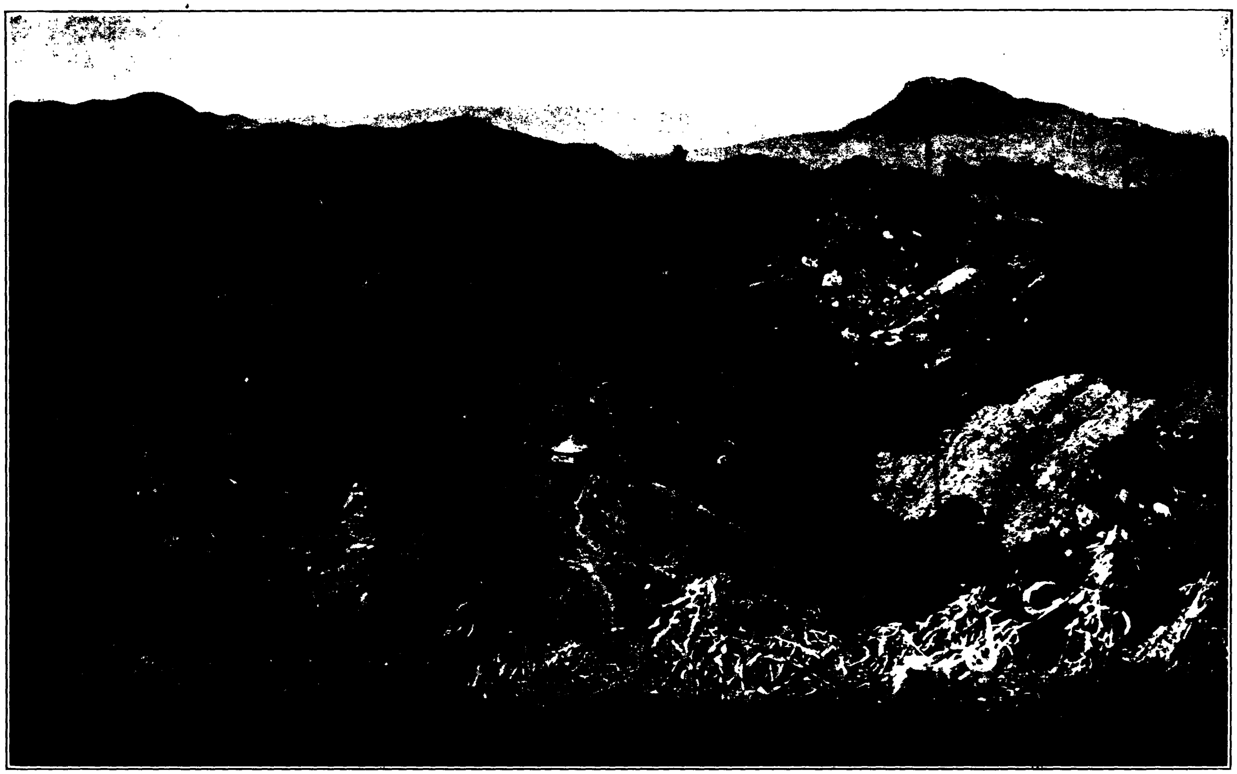

PLATE I.

Although the region is maturely dissected, it may be seen that the majority of the hilltops come up to a common plane which does not signify a peneplain, but simply the surface of the great lava flow which just antedated the deposition of the Miocene limestone.

This section is very rugged and at first sight quite forbidding. The larger part of the people live in barrios and reconcentration camps on narrow ridges. These camps were established in 1903 and 1904 by the Constabulary to protect the people from some bands of "pulajanes" infesting the country at that time. Although at first sight the country would appear to be barren and unproductive, the wash from its decaying limestone and the disintegrated andesite produce a fairly rich soil. I have seen some very good corn in this section. Plate I is a view of the Cot-Cot country which very well shows the general appearance of this dissected Tertiary lava field.

The most widespread formation is a porphyritic rock which will be described at greater length further on. In many hand specimens it is clearly an andesite, with feldspar and pyroxene phenecrysts in a fine groundmass; in others, all which can be seen are white feldspars (usually kaolinized) in a fine-grained, green groundmass.

A series of shales, sandstones and graywackes are found to be exposed where the streams have cut down through this lava capping, where the talus is not too thick, dipping sometimes at high angles and with constantly changing strikes. It would be highly advantageous to be able to map these, giving their underground courses, but the outcrops are not sufficiently numerous or contiguous to do this with any assurance of safety.

There has been some mineralization in the vicinity of Acsubing Mountain, as galena is found in veins in the andesite. We have been able to see these veins only in two localities, but these limited observations led us to believe that the deposits are in the form of a *"stock work."*

I have been unable to find any coal in this series, nor have I encountered any fossils, but I have no reason to doubt that the series belongs to the coal measures. A portion of it may be terrestrial in origin, as seems to be the case with the formations to the north of the Cot-Cot and the east of Mount Licos.

THE MOUNT LICOS REGION.

This includes both the old Compostela and the Camansi workings and was the principal field in Spanish days. This portion of the district is quite different from the preceding, in that the igneous extrusives are lacking over most of the territory. As the western part of the field abuts on the igneous basement complex, in our mapping we have kept well to the east. By referring to the map, a belt which widens and narrows (represented by the blue color) may be seen; in general it runs in a northeast-southwest direction. This is the productive portion of the coal measures; to the east it dips beneath the limestone and still farther to the east it undoubtedly would be found, although at no inconsiderable depth. This belt of productive measures can readily be traced in a general way by the topography and the vegetation. The topography is marked by moderate, gentle slopes and rounded contours. The vegetation consists largely of rank *cogon* and *taláhib*, with absolutely no forests.

Mount Licos is a long, irregular mountain the highest point of which is just above the Compostela workings. From its height of 520 meters (1,700 feet) it declines gradually to the northeast to the Danao River. This eminence is capped with a white, orbitoidal limestone of 30 to 150 meters (100 to 500 feet) in thickness. This capping is very rugged, exceedingly conspicuous and easily traced; it is fairly well, but not densely, clad with forest trees. To the north of the mountain we find a great mass of conglomerate, not basal, but such a formation as is characteristic of coal fields. I have called this the barren measures. Its thickness is at least several hundred feet, although just how great it is I am unable to say. Although it is treeless, it is marked by its accentuated relief. This formation will be treated of more fully in a subsequent portion of this paper.

THE CAJUMAYJUMAYAN VALLEY.

Another field containing coal lies to the north of Sili Peak and Lantauan ridge. This is simply an extension of those to the south. Its structure, to judge from rather incomplete data, is that of a basin or syncline. Practically the same formations as those mentioned under the Mount Licos region occur here and in the same order. The most characteristic feature of the field is the hogback in the center of the basin, which is a remnant of the upper or barren conglomerate. There are five seams in this valley, as is the case in the others.

TABLE III.—*Stratigraphy of the Compostela-Danao region.*

Recent.	Alluvial deposits in streams and extensive and thick talus on all slopes; and travertine.	
	UNCONFORMITY.	
Miocene.	Upper white limestone, coralline and containing *Orbitoides*, *Lithothamnium* and many mollusca in its basal portion.	
Oligocene.	Shaly limestone—cream colored and soft—unfossiliferous.	
	UNCONFORMITY.	
	Extrusive rocks—chiefly andesite.	
Eocene.	Terrestrial deposits consisting largely of conglomerate—showing much oxidation.	
	UNCONFORMITY (?)	
	Coarse gray sandstone.	90 to 150 meters (300 to 500 feet.)
	Coal measure shales including five coal seams.	

UNCONFORMITY.

Pre-Eocene (?) Basal diorite and conglomerate.

STRATIGRAPHY.

I have compiled in Table III a statement of the stratigraphic column which gives, as nearly as I now know it, the relation of the different formations in this part of the island. Beginning with the lowest, we have the basal complex largely composed of diorite and, as a closely related part of this, the basal conglomerate. Its extension where it comes to the surface can be seen on the map, represented by the red single-cross-hatched color. It occupies a portion of its western part, in fact the map was not extended farther because of it. A typical diorite is found in the winding gorge of the Danao River, in every respect resembling the basal rock of Masbate, Benguet, etc. A typical development of basal conglomerate is to be seen in portions of the river course, while in others but little of this can be observed.

THE IGNEOUS BASE.

For some time I was puzzled by the particular phase of igneous rock constituting the hills on the left, or north side, of the Danao River. Here the rock is more of a porphyry than holocrystalline. From all the evidence I was able to procure the rock exposed on this higher ground is merely a porphyritic facies of the diorite, as would be natural to expect in the upper part of the mass, where the cooling had been more rapid. A feature of this rock is the innumerable, minute, calcite veins cutting through it without definite system.

The following is a description of this rock from the region of Sili Creek, not far from the coal measures:

CEBU NO. 5 (DILWORTH).—DIORITE PORPHYRY.

Hand specimen.—A dark colored, fine-grained, igneous rock. The only minerals identifiable in the hand specimen are dark green plagioclase and rare specks of magnetite.

Microscopic (*2 sections*).—The rock is composed almost entirely of feldspar, rather decomposed. There are several porphyritic crystals reaching a maximum size of 2 by 1 millimeters, but the majority are small laths. About 5 per cent of the feldspars seem to be orthoclase. No good determinations could be made of the plagioclases, but six rather doubtful ones gave three of acid labradorite and three of basic oligoclase. Many of the feldspars show good zonal structure. Several, especially among the smaller laths, are bent.

Biotite is present in all stages of decomposition, but is always well chloritized. There are no well-defined plates.

Quartz occurs in small and inconspicuous grains. It forms a very small part of the rock and is accessory rather than essential.

There are a large number of small crystals of titaniferous magnetite or limonite, generally associated with the biotite. The presence of titanium is shown by the dirty white titanite, which surrounds these crystals.

Secondary minerals are: Kaolin and sericite, along cracks in the feldspars; chlorite replacing biotite; patches of calcite; and titanite associated with the magnetite.

BASAL CONGLOMERATE.

The basal conglomerate, in some places at least, overlies the igneous basement; however, this does not appear anywhere to have the strong development it has in the Benguet region.

This conglomerate marks an unconformity, probably the greatest break in the stratigraphic column within the limits of the Archipelago, and it differs from the conglomerate in the coal measures by the fact that all the included pebbles are igneous, whereas in the case of the latter they are mixed with sandstone, shale, etc., clearly showing that they were not altogether derived from the basal mass. It would be difficult to determine the age of the basement complex, but it is certainly pre-Miocene.

In the region of Sili Creek we find a formation which, taken altogether, I call a greenstone. Some phases of this are certainly diorite, others are porphyritic, and near the head of the creek, at 380 meters (1,250 feet), there is a dark phase of rock which may be a diabase and hence a dike, but the extremely limited exposure of the outcrop prevented my being absolutely certain. A very important question affecting our knowledge of the extent of the coal on the north side of the Danao River, is whether or not this upper portion of the formation in Sili Creek might not be an intrusive or even an extrusive, like the flow south of the Cot-Cot River. We might then, in the event of this proving to be so, expect to find the coal beds below and possibly exposed somewhere in the bed of Sili Creek. Nowhere in this channel was any coal formation encountered, but on the other hand a clean section of several hundred feet of greenstone was observed.

I found the greenstone in this stream at an elevation of 238 meters (780 feet) with marked jointing, the directions and dips of which are as follows: S. 25° E., dip 60° NE.; N. 82° W., dip 76° NE.; S. 40° W., dip 40° SE.

THE COAL MEASURES.

I have divided the coal measures into two subdivisions for purposes of convenience in description, although in the field I have found no sharp line between these. The lower part of the measures consists of gray shales, the upper portion of a coarse, gray sandstone. There are five coal seams. I have mapped the slates and sandstone under one color (the blue), because it is practically impossible to separate them in the field.

The photograph (Pl. II) shows the contact of the coal measure shales with the basal conglomerate. It also shows the intense plication in the weaker rocks, where they abut on the resistant igneous base.

The shales, as this stream (the Suqui) is ascended, become more and more coarse until the coal seams are encountered where a grit appears. There are about 60 or 100 centimeters (2 or 3 feet) of clay and shale, just above the "Enriqueta" vein, then the coarse gray sandstone comes

PLATE II.

in, and from there on up to the base of the limestone all outcrops (which are very few indeed) show sandstone. This sandstone in its composition very clearly demonstrates that it was largely derived from the igneous material near at hand and we may infer that the only high land at the time of its formation consisted of the diorite and greenstone hills which stood above and immediately to the westward of the tidal swamps in which the coal was forming. We can estimate the thickness of the sandstone only approximately, but considering the outcrops on the slopes of Mount Licos, I believe it to be not over 150 meters (500 feet). It is very improbable that there is an unconformity between the shales and the sandstone. Numerous observations of the strike and dip of these formations show the strike in general to vary from N. 27° E. to N. 55° E. and the dip anywhere from 20° to 90° SE. In the region to the west of the Mount Licos workings and in the arroyos which head in or near the igneous formation, I found some westward dips at rather high angles, showing complete overturn, but this is to be expected as the igneous rock is approached.

There is every reason to believe that the limestone rests unconformably above the sandstone. This formation has two well-marked phases; the lower characterized by being softer, more of a yellowish color and so far appearing to be unfossiliferous, it also is more stratified than the upper part; the upper portion is a very white, hard, sometimes crystalline limestone, revealing little regularity of structure.

Before describing it in detail I should discuss two other formations which occur in the stratigraphic column between the sandstone and the limestone.

Both of these are terrestrial deposits—the first or lower is a conglomerate made up of igneous sandstone, shale and slaty pebbles. The very reddish-brown color of both the pebbles and the matrix, the evidence of oxidation and the general heterogeneous character of the pebbles show pretty clearly that this formation is in the nature of a flood-plain deposit, or as Professor Barrell would call it, piedmont deposit. On the map this is denoted by the brown color, and the formation is to be found extensively developed on the east side of Mount Licos. In places it is at least 90 meters (300 feet) thick, and it may be more. A remnant of it is found in the hogback in the bottom of the Cajumayjumayan Valley and in several other isolated patches above the coal. The pebbles in this formation are usually small; I saw none exceeding 2 inches in diameter.

The second terrestrial deposit of consequence in this field is the andesite just south of the Cot-Cot, the extension of which I have already alluded to. I have mapped a series with this formation, which is rather difficult to demarcate and separate from the andesite because when the two are weathered they strongly resemble one another. This series Abella alluded to as *tobas,* which means a clastic rock derived from the wear of other rocks, chiefly igneous; we would call them graywackes. Some rocks of pyroclastic origin are also doubtless associated with these. The best place to see these graywackes is in the gorge of the Cot-Cot just above Muao, where they can be seen dipping at a low angle to the east; and above them at approximately 300 meters (1,000 feet) elevation is the andesite capping.

Petrographic descriptions of both the andesite and the detrital material made for me by my colleague, Mr. H. G. Ferguson, are given below:

CEBU NO. 45.—ARKOSE.

Hand specimen.—Extremely fine grained, grayish rock, the distinguishable minerals of which are pink feldspars, quartz, magnetite and occasional hornblende (?). The grains are all very small and approximately the same size.

Microscopic.—The rock is much decomposed, especially the feldspars. Feldspar is the most prominent mineral, and is chiefly orthoclase, but one grain of albite was found. There are no perfect crystals, but occasional crystal faces occur. Quartz is rather rare in definite grains, but seems to fill spaces between other crystals. Biotite occurs in small amounts, but in bent and frayed fragments rather than plates. Occasional fragments of hornblende crystals are present. Magnetite occurs in numerous, small grains, often partly altered to limonite. One grain of topaz (?), a few minute grains of olivine (?) and numerous very minute grains (diameter generally about 0.01 millimeter) of a mineral with high refractive index and rather high double refraction, apparently titanite, are the accessory minerals.

The rock shows no definite structure. The grains vary in size, but never exceed 0.25 millimeter and perfect crystals are never found. The biotite especially presents a fragmental appearance. I believe the rock to be an arkose, formed by the decay of a trachytic igneous rock and with only slight transportation, as there is no evidence of assortment of the minerals.

CEBU NO. 70.—ANDESITE.

Hand specimen.—The specimen is taken from the contact of two igneous rocks of different texture, one a greenish-gray, aphanitic rock and the other more porphyritic, consisting of greenish and glassy-white feldspars, in a purplish groundmass. The contact is a shearing plane, stained with iron oxide.

Microscopic (2 slides, both from the porphyritic rock).—Feldspars in idiomorphic crystals are very prominent, but are all completely decomposed, chiefly to sericite aggregates, and are also to a large extent replaced by calcite. One doubtful case of albite twinning was found, which gave extinction angles corresponding to oligoclase.

Biotite is present in considerable amount (possibly 5 per cent of the slide). This mineral is interesting as it shows different stages of decomposition. In part it has simply lost a portion of its iron content and become more hydrated, showing in plane polarized light a greenish pleochroism and under crossed nichols a much lower double refraction than normal biotite, the colors ranging from first order gray to first order yellow. For a part of the mineral, however, the alteration has been more complete and the biotite has gone over to chlorite; sometimes both stages can be observed in the same crystal. Biotite has also suffered somewhat from replacement by calcite.

Other dark silicates if originally present have been altered beyond recognition.

Magnetite is present both in large grains (largest 0.3 by 0.2 millimeter) associated with the biotite, and in small specks in the groundmass. It is generally fresh, but rarely is somewhat decomposed, staining the surrounding portion of the slide with iron oxide.

The groundmass is for the most part a mass of cloudy decomposition products and secondary calcite. Occasional remnants of feldspar microlites can be made out. There are also numerous small rods and specks, visible only with the highest power objective. These are colorless, brown and opaque, but not clearly resolvable. Numerous small specks of magnetite also occur.

THE UPPER LIMESTONE.

The upper limestone is quite hard, dazzling white on fresh exposures and the boundary of the formation is readily followed even where it happens to be covered with talus. This formation is found in more or less detached areas, it being remnants of what was most probably a continuous blanket. It rarely reveals any stratification and hence its dip and strike is generally a matter of conjecture. It is my conception that prior to the formation of this blanket of limestone there existed many irregularities in the surface, due to previous erosion, and that the limestone deposit first filled in these irregularities.

This horizon of the limestone in places is quite coralline, with many of the characteristic genera now growing in the surrounding reefs. These corals now appear to be segregated in colonies, although there may previously have been a continuous reef formation of which we have merely the remnants left, the other portion having been destroyed by erosion.

The lower part of the formation is in places very fossiliferous and the mollusca now fossilized undoubtedly lived in colonies, as we know them to do to-day. At an elevation of 275 meters (900 feet) and near the barrio of Mabasa I found a great many fossils which had weathered out of the rock. They are all casts and a number of them are in poor condition. (Pls. III and IV.) Some of the genera represented are:

Cerithium.
Fusus.
Turbo.
Natica.
Teredina.
Trochus.
Bulla.
Pectin.
Dosinia.
Conus.

It is not my intention to make this a paleontologic discussion and therefore I shall leave these fossils with the statement that I have compared them with many of Martin's illustrations in his monograph on the Tertiary of Java and have found many that I believe to be identical with those from which his illustrations are taken.

I have thought it best not to treat of the paleontology at this time, as it is my purpose later to prepare a monograph on the Tertiary fossils of the Philippines.

Foraminiferal tests can be found at nearly any point where a piece of this limestone is chipped. The genus *Lepidocyclina* (*Orbitoides*) predominates. Generally, these fossils are found most thickly near the base of the upper white limestone, they are much larger in this situation than in the upper horizons and I believe them to be of quite a different species. The two best localities in which to find these *Orbitoides* are at Mount Lantauan, near the large sink hole at the eastern end of the ridge, and at 320 meters (1,050 feet) elevation on the southwest slope of Mount Licos, where the trail passes around to the coal workings.

Another characteristic form found in this limestone is the marine alga *Lithothamnium ramossisium* Reuss. This is shown in two sections on Plates III and IV.

There seems to be little question but that this is the same horizon as the Baguio, Theila Pass, Binangonan and Masbate upper limestones. Following Martin[5] in his work on Java, and Newton and Holland[6] on Formosan fossils, I have been inclined to assign this formation, at least this horizon of it, to the Miocene, although fossils from a very similar limestone which I have also examined in the field in Batan Island have been classified by a European paleontologist[7] as Oligocene. The fossils so classified were collected by Mr. O. Halvorsen Reinholt and he simply states that they came from above the coal. However, I suspect, judging from similar forms which I collected myself on Batan Island, that his forms did not come from the uppermost horizon, therefore, future search and study of the fossils already collected may reveal this Oligocene horizon in Cebu.

It will be of interest to attempt to correlate our Cebu section with Verbeek's[8] classification of the Eocene in Java as amended in 1892, which is as follows:

Stage IV. Orbitoides—Miocene.
III. Marl sandstone—Oligocene.
II. Quartz-sandstone—Eocene.
I. Breccia stage—basal conglomerate.

This scheme is more in accord with Martin's idea as expressed in 1900, as follows:

> Quaternary; consisting of fluviatile and marine deposits, the latter rich in Mollusca, and at some localities remains of whales.
>
> Upper Pliocene; represented by the Rendon Beds, rich in remains of *Stegodon* and *Cervus*, containing also *Pithecanthropus erectus* Dub.
>
> Pliocene-Miocene, or the Java series, possibly including some pre-Miocene rocks. This constitutes the greater part of the Island of Java and most of the fossils from the island which have been described come from it. Among them are

---

[5] Tertiärschichten auf Java, Leyden (1880).

[6] *J. Coll. Sci. Imp. Univ.*, Tokyo (1902), **17**, Art. 6.

[7] Reinholt, O. Halvorsen: *Engineering Journ.* (1906), **30**, 510.

[8] Neues Jahrb. fur Mineralogie, etc. (1892), 66.

PLATE III.

PLATE IV.

Lepidocyclina and *Cycloclypeus*. This series extends northward through the Philippines to central Japan.

Eocene; marine beds of small extent with *Nummulites, Alveolina* and *Orthophragmina*. They contain coal.

Cretaceous limestone with *Obitolina* from *Banjoemaas*. This rock is not known to exist at other points in Java.

By comparison with the table on page 390 it will be seen that my column is fairly well in accord with Verbeek's divisions in Java, and with Martin's Pliocene-Miocene or Java series.

Recent formations.—The latest deposits to be laid down in this region are those which are still forming in the river bottoms, on the coastal plains where the streams issue from the mountains, and along the coast, but in our limited field we need only refer to two of these, the river-bottom deposits and the talus slopes, for these are in part alluvial, although gravity is probably much the most potent agent in producing the latter, whereas water is the cause of the former.

All the waters in this region in addition to the mechanical detritus of the streams, carry a large quantity of lime in solution. This is generally deposited on the shales of the coal measures. I have picked up fresh-water snail shells which had a coating of half an inch in thickness of calcium carbonate.

STRUCTURE.

The importance of geologic structure is nowhere exemplified as it is in a coal field. Not only the condition of the coal is generally greatly changed by an increase in the inclination of the strata, but the cost of mining is enhanced almost in geometric ratio under certain conditions; an instance of such conditions being those under which the miner is forced to work down the dip, hauling the coal up an incline by steam or electricity, and where it is necessary to pump. In discussing the structure of this district I shall merely make mention of the structure of the coal measures. The general strike of the formations on the east coast of Cebu is north and south, but in the Compostela-Danao region the *Cordillera* swings somewhat to the east and likewise the strike of the coal measures changes to about N. 25° E. The dip, which on this side is generally easterly, changes to southeast. It is not uniform, uninterrupted and always to the east, but in some places the formation is plicated to an extreme degree, with westerly dips. An instance of the close folding is shown in the cut of the tramroad just below the Camarin at Camansi, and again in Suqui Creek, where the igneous rock is approached; besides this there seems to be abundant indication of a minor north and south cross folding, but this is not a bad feature, as it is not noticeable except over great distances.

I am not able to assert that much indication of faulting appears on the surface, although I suspect it to have been considerable, but of a minor character, in this district and until more underground data are acquired, I shall dispense with further discussion of this feature, merely stating that in the very limited workings of the Spaniards, several faults were encountered, but according to Abella, who examined them all, they were neither sufficiently great nor numerous to cause any serious difficulty in mining operations.

I shall now briefly summarize the geological history of this district, before passing on to the discussion of its economic phases. We may think of a basal mass of igneous rock with little or no sediments covering it. Whether this was a part of the mainland of a then extended continent, or an outlying island mass, we can not at present say. This igneous mass must have had some elevation, otherwise the later sediments could not have been formed. About this igneous mass a coral platform undoubtedly formed in places. This grew up to a limiting plane, the sea level. Upon this, the detritus of the hills poured and made a shelf. This substructure of coral may have been lacking in other parts. At all events, there were low, tidal flats, girting the elevated igneous mass at the beginning of the Eocene. These flats were the sites of unusually rank forests, and deposits began to form which afterwards were to become coal. Sinking of the whole mass must have begun at this time and later elevation again occurred. There were periods of quiescence, followed by oscillations of level, in which shales and coarse sandstone were alternately deposited above the coal beds. Finally, there came at the close of the Eocene a subsidence so great that the entire mass sank under the sea and a coral mantle was deposited over the whole region. At the close of the Miocene, which was the period of the deposition of the limestone, there occurred a period of uplift and rather pronounced folding of the strata. Since that time erosion has denuded the area of a large part of its mantle of limestone, uncovering the coal-bearing formations below.

GEOLOGY: ECONOMIC.

HISTORY OF THE DISTRICT.

As the complete history of the discovery of coal and operations in Cebu is recorded in "The Coal Measures of the Philippines"[9] which is simply a compilation and translation from the Spanish records, I will only in this place summarize what was given.

Coal was discovered in Cebu in 1827. The first concessions in the Compostela-Danao region were solicited by Isaac Conui in 1871. A wagon road was built from Cot-Cot cove to the workings at Dapdap in 1877. The formation of the association known as the *Sociedad Nuevo Langrea* and the beginning of actual work took place about 1890. The construction of a tramroad from Danao to Camansi, and from Compostela to Mount Licos, was undertaken in 1895. Then followed the Spanish-American war in 1898. In this year all the concessions in this district came into the hands of Mr. Enrique Spitz. These concessions have

[9] Burritt, Chas. H.: Wash. (1901).

changed hands again and are controlled by the Insular Coal Company, which is now in the field carrying on exploratory work.

Operations.—It will be sufficient at the present time to state that two companies, of which the Insular Coal Company is one and the other a New York syndicate, are vigorously investigating these fields; the Insular Coal Company in the Mount Licos and Camansi regions, the latter in the Cajumayjumayan Valley. As both these companies seem to be very much in earnest and backed by responsible men who command considerable capital, we should obtain as a result of their investigations a far more thorough knowledge of these fields than we now have.

The district is one in which the geology is very complicated but not more so, it is believed, than that of other coal-bearing areas of the Archipelago. It certainly has some features possessing advantages over other parts of the Island of Cebu, although coal may be found in almost all districts of the island.

COAL SEAMS.

The three fields at present being developed are rather limited, but amply sufficient for a considerable production of coal. Various estimates have been made of the possible tonnage, some of which are founded on guesswork and are very wild. A very conservative estimate would be 2,000,000 workable tons in the Cajumayjumayan valley and two to four million in the combined Mount Licos and Camansi fields. The coal seams are rather highly inclined, from 30° to 90°, which would necessitate some system like the "Battery" being employed. The proper drainage of the workings will be a serious factor. Both the roof and floor are weak, the floor being of shale and fire clay, and the roof of shale or friable sandstone. Great care will need to be taken in timbering. There will also be increased expense for timber, because the greater part of it will need to be brought from some distance, probably from another island (see Forester Everett's timber report in the first part of this paper, p. 384). Methods for preservation of mine timbers must be devised. However, when molave is used the timbers will last for many years; in fact I have examined such timbers which were for nearly ten years completely buried in loose earth in the "Enrique Abella" tunnel and they were perfectly sound. It must be remembered that timber does not last underground proportionately as long in the tropics as in higher latitudes. Forepoling and lagging will be necessary in the shafting and drifts.

There is evidence of considerable minor faulting, but probably none which will seriously affect mining operations. There are five known coal seams, at least three of which should be profitable; two of these are over ten feet thick in one part of the field. The following beds were encountered at Mount Licos, from west to east, that is from lowest to highest:

1. The "Cármen;" thickness 1.60 meters, strike NE.–SW., dip 30′ SE.; 40 meters interval.

2. "Esperanza;" 50 centimeters, strike the same as above, dip same; 9 meters interval.

3. "Enrique Abella;" thickness 1.20 to 1.50 meters, strike N. 23° E., dip 40° to SE.; 40 meters interval.

4. "Pilarica;" thickness 1.40 meters, strike N. 23° E., dip 30° SE.

There formerly existed over 300 meters of drifts at the old Licos workings. About 100 tons of coal, taken from the "Esperanza," "Ramoncita" and "Enrique Abella" galleries have been on the dump for three or four years. In this time the coal has not taken fire, nor has it "air-slacked" very greatly, which bodes good for its handling and storing. The coal throughout the district is remarkably free from dirt, "butter" and "bone" and is quite low in sulphur.

We believe that this coal will ultimately find its greatest utility as a gas producer and with this end in view it should be mentioned that Dr. Cox, of this Bureau, is devoting much of his time to experimenting on this problem. It is hoped that at no distant date the Bureau of Science will be able to make a practical demonstration in this direction. The Philippine Commission has just appropriated a sum sufficient to cover the expense of installing a producer gas plant at the laboratory of this Bureau.

Dr. A. J. Cox has added a contribution from his own chemical investigations. His report is as follows:

> The quality of the coal from the Cebu fields is no exception to the general average of this commodity in the Philippines. I have been over a large part of the territory and have analyzed samples from all the sources where coal is known to occur. None of the samples show a woody structure, and in general the coal is compact, lustrous and commonly has both hackly and conchoidal fracture. The coal as mined is very black, but when finely powdered (60 mesh) it assumes a tinge of brown. It is of the non-coking, sub-bituminous to bituminous variety. The latter class is perhaps best represented by that from the Compostela region. In this field the active work which is now being carried on is beyond the prospecting stage, so that more definite information is at hand regarding the extent of the deposits and thoroughly average samples have been obtained for chemical work. A study of the volatile matter from this coal shows it to contain a fairly good percentage of heavy hydrocarbons and it could probably be used successfully as a gas coal. The composition of the gas and the yield from this coal is not greatly different from that obtained from Polillo[10] coal. Attention has already been directed to the peculiar, elliptical, pit-like markings which characterize Compostela coal.[11]
>
> I have analyzed a great many samples from both the Carmen and Compostela fields. Some of the results have already been published[12] and other more recent determinations will be printed in a future communication. Barring diluents, water, ash, sulphur, etc., and considering the relation of the percentage of volatile combustible matter to fixed carbon, which by many authorities is taken

---

[10] Cox, A. J.: *This Journal* (1906), **1**, 893.

[11] *Ibid, Sec. "A," Gen. Sci.* (1907), **2**, 50.

[12] *Ibid,* 52.

as the criterion of classification, there is a surprising regularity in the analyses of all of the samples taken from a single field. The averages of all the samples give the following results:

Averages of analyses of Cebu coals.

[The figures give percentages.]

Constituent.	For the Carmen region.			For the Compostela region.		
	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
Moisture	13.5	21.6	16.70	7.5	9.5	8.60
Volatile combustible matter	33	38	35.10	35.1	38	36.95
Fixed carbon	38.7	49.3	43.92	51.3	52.8	51.75
Ash	1	8	4.28	1	3.8	2.70
Total			100			100
Sulphur	.1	2.7	.67	.2	1.3	.71
Calorific value in calories	4,820	5,920	5,330			6,380

Although a careful study has been made of all of the Philippine coals thus far discovered, not a single sample of coking coal has been found. The usefulness of a coke in this Archipelago is well recognized, for were it to be readily accessible the iron industry would be in line for development. In view of this I have tried to make coke in various ways. The coal from the Compostela region yields a certain per cent of tar and it was thought that by mixing this product with the coal itself before charging into the coke oven, a good coke might result. Several experiments were made. The pulverized coal and tar in varying amounts up to 12 per cent of the weight of the coal were warmed to 110°, intimately mixed and then subjected to a heat similar to that of a coke oven; in fact, the heat was varied to cover the various ranges present in coke ovens. All experiments gave negative results. In none of them was there more than a semblance of coke, consequently for the present we must give up the hope of obtaining coke in these Islands.

I have added below a copy of an analysis of the upper limestone which will be of interest in view of the fact that possibly a cement plant will be erected in this region at some future date. As this paper has been devoted almost entirely to the question of the coal, I shall not discuss this matter further at the present time.

The absence of magnesia which seems to be characteristic of recent limestones, should be noted.

Analysis of the limestone.

	Per cent.
Insoluble acid	0.36
Fe_2O_3 Al_2O_3	.18
CaO	55.62
Loss on ignition	43.50
H_2O at 110° C.	.17
Total	99.83

LABOR.

Labor conditions on the whole are good in Cebu, and in the Compostela-Danao district the natives have more or less familiarity with underground work, gained by experience of a score of years under the tutelage of the Spaniards. The present wage in this field is 40 centavos and subsistence, for the outside laborers, and 50 centavos for the underground man; however, of late the Insular Coal Company has found it best to pay so much a foot for driving a drift. The price per foot will of course vary according to conditions. The Philippine Railroad Construction Company has found the native labor to be very satisfactory. In their work thousands of natives are used at a wage of 50 centavos and subsistence. The subsistence is arranged for by contract with a Chinaman. It is the belief of many in these Islands that the Visayans are the best laborers of any of the tribal groups. However, this is a matter more or less of personal opinion.

TRANSPORTATION.

The new railroad from the city of Cebu to Danao, a distance of 32 kilometers (20 miles), is completed at this date. From Danao to the Camansi workings is a distance of about 8 kilometers (5 miles) with a rise of 75 meters (250 feet). There is now a tramroad over this course, an heirloom from the Spanish régime; but this will need to be replaced by new rails and more clearing will have to be done before any extensive work is undertaken. The transportation problem in the other parts of the district will not be so simple and I believe overhead cables or inclined planes will be found to be necessary.

RECOMMENDATIONS.

I would caution any company which intends any great outlay of money, thoroughly to explore the field with drills or by means of numerous drifts. I do not believe the diamond drill will be best for these soft formations, but a churn or a calyx drill should be on hand for certain parts of the work. The disadvantage in using such a drill is the difficulty found in obtaining an accurate record of the formations encountered. It would be foolish, judging from the folded condition of the rocks, to suppose that the beds will continue as they appear along the outcrops. Without more records from shafts, drifts or bore holes, I should consider any estimates as to the quantity of coal, the position of the beds and their condition to be little more than guesswork.

The vicinity of Luguayan Creek on the eastern edge of the map should be prospected, as here the coal is found exposed below the upper conglomerate. It is probable that in this position the beds are less folded than they are farther to the west. I should even go so far as to predict the finding of good, regular beds underlying the more level country near

Danao. The saving in transportation and the greater regularity of the beds might more than offset the cost of sinking a shaft and pumping.

I may also add that drilling in the vicinity of the andesite formation might, not improbably, discover anthracitized coal, should the andesite come in contact with the coal bed at any point. This has been known to be the case in the anthracite region of Colorado, in the United States.

In conclusion it should be said that the coal formation in this district does not differ greatly from that of Batan Island and operations in either field will necessitate considerable outlay of capital. Furthermore, the problem connected with coal mining in either field will tax the ingenuity of any engineer and it will be a saving in the long run to spare nothing in order to get the best man available.

ILLUSTRATIONS.

Facing page
PLATE 1. View of the country in the vicinity of Siglo XX. Mount Licos in the right background. The formation in the foreground is extrusive igneous rock 389
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IX. Characteristic vegetation and topography in the coal regions.
X. Showing structure in shales on the Parel River.
XI. Cirque-like valley in the hills to the west of Camp Clark.
XII. Rubble limestone exposed in a gorge of the Danao River.
XIII. The upper limestone dipping to the east in a gorge of the Danao River.
XIV. The "Enrique Abella" entry, Compostela mines.
XV. Plan of workings of the Compostela mines.
Map No. 1.
Map No. 2.

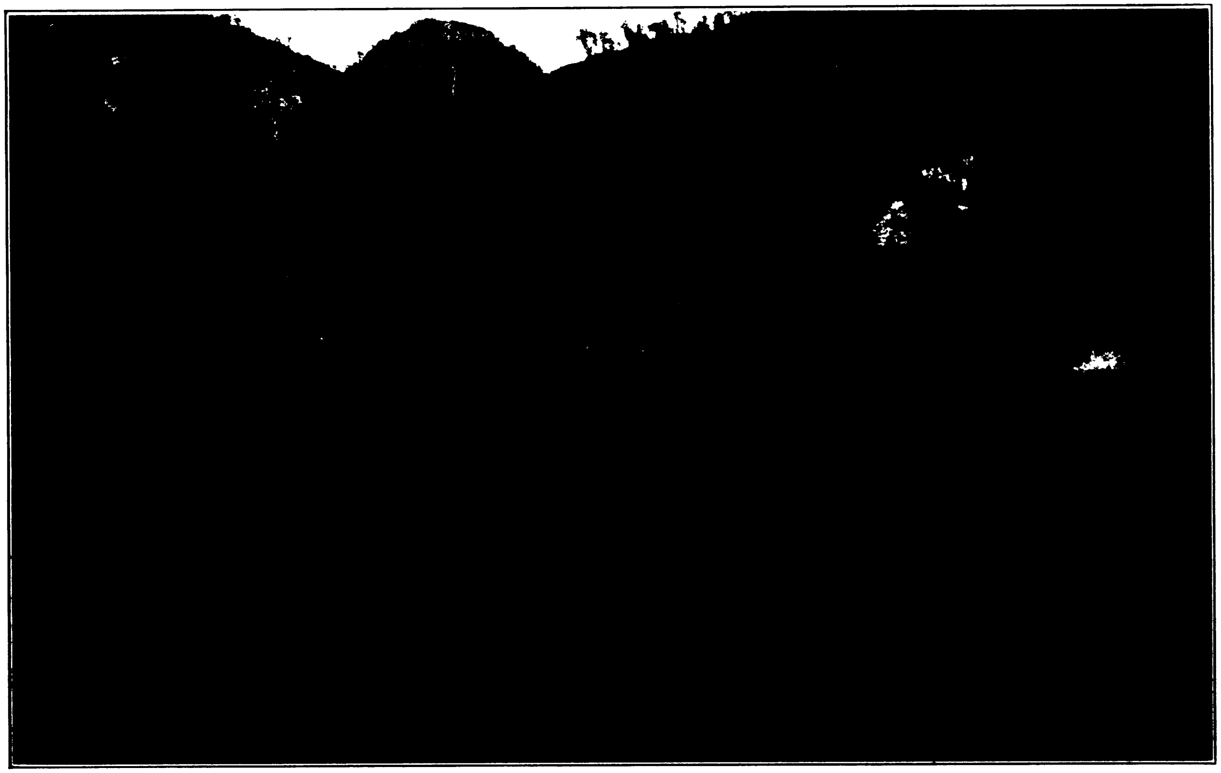


PLATE V.

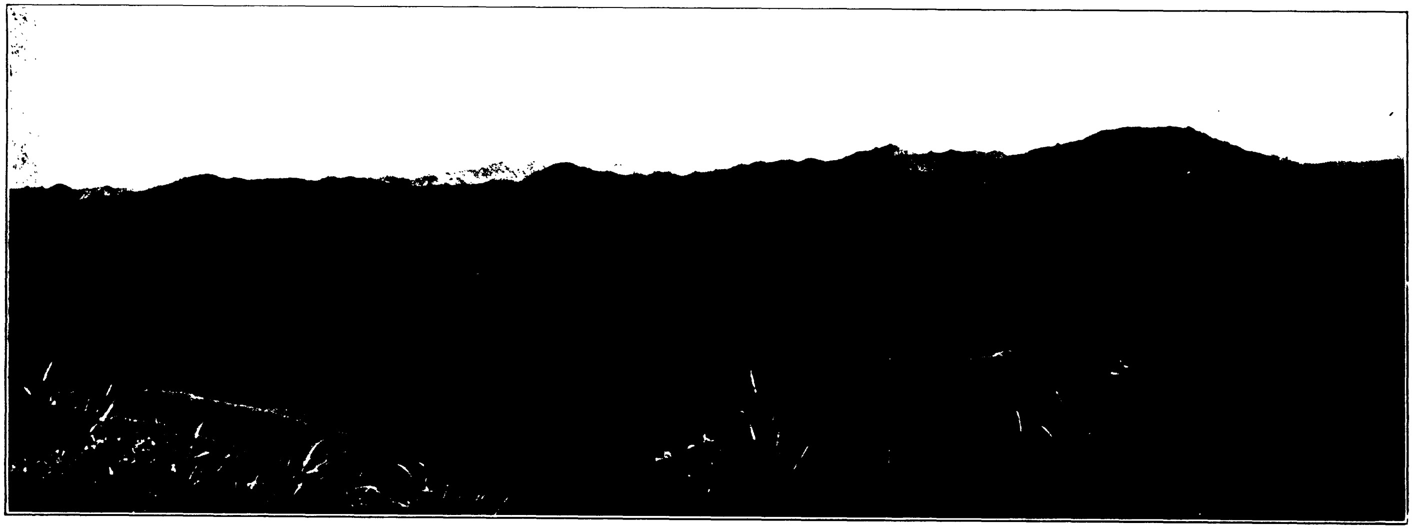


PLATE VI.

PLATE VII.

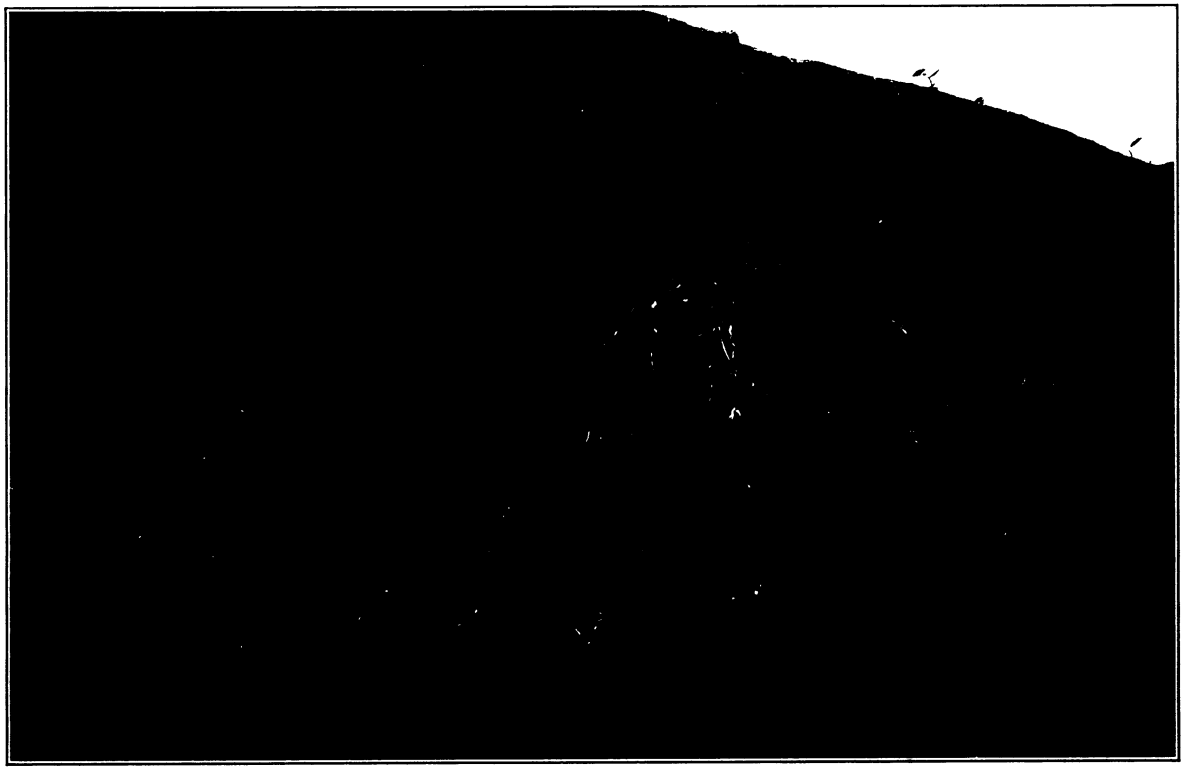


PLATE VIII.

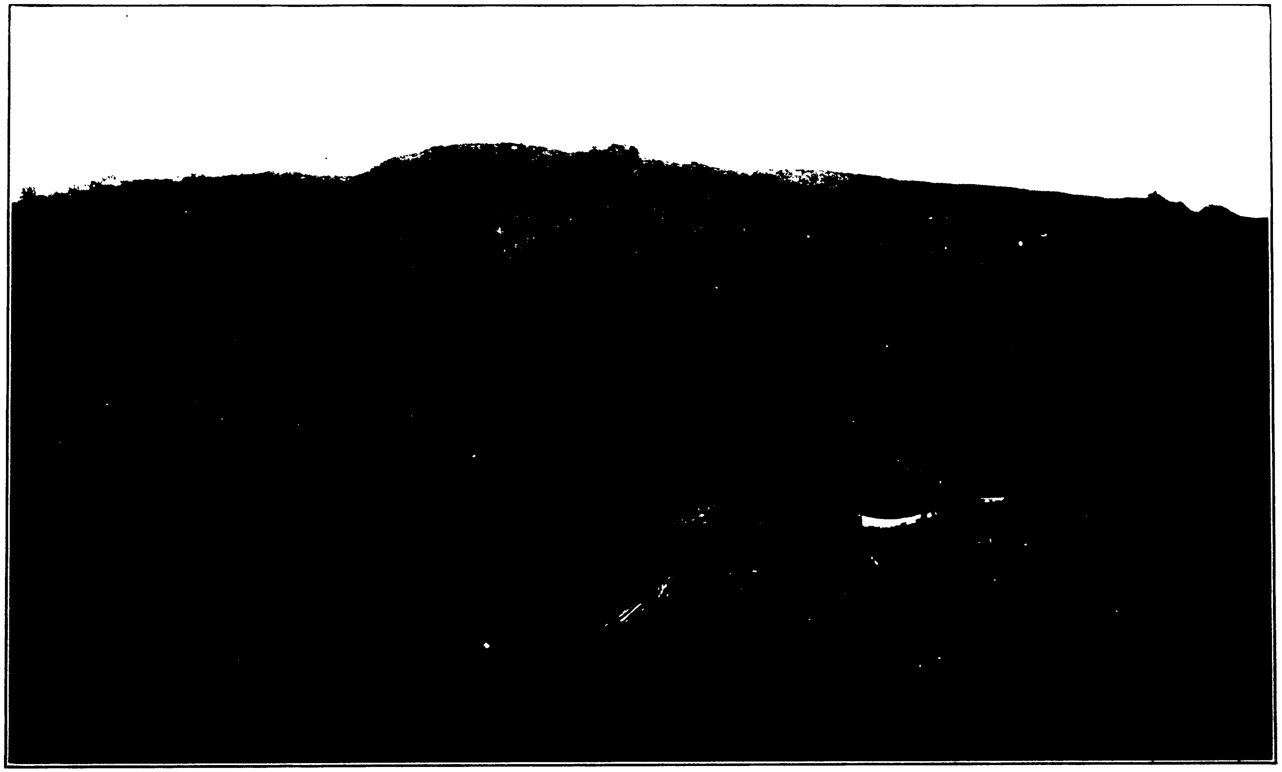


PLATE IX.

PLATE X.

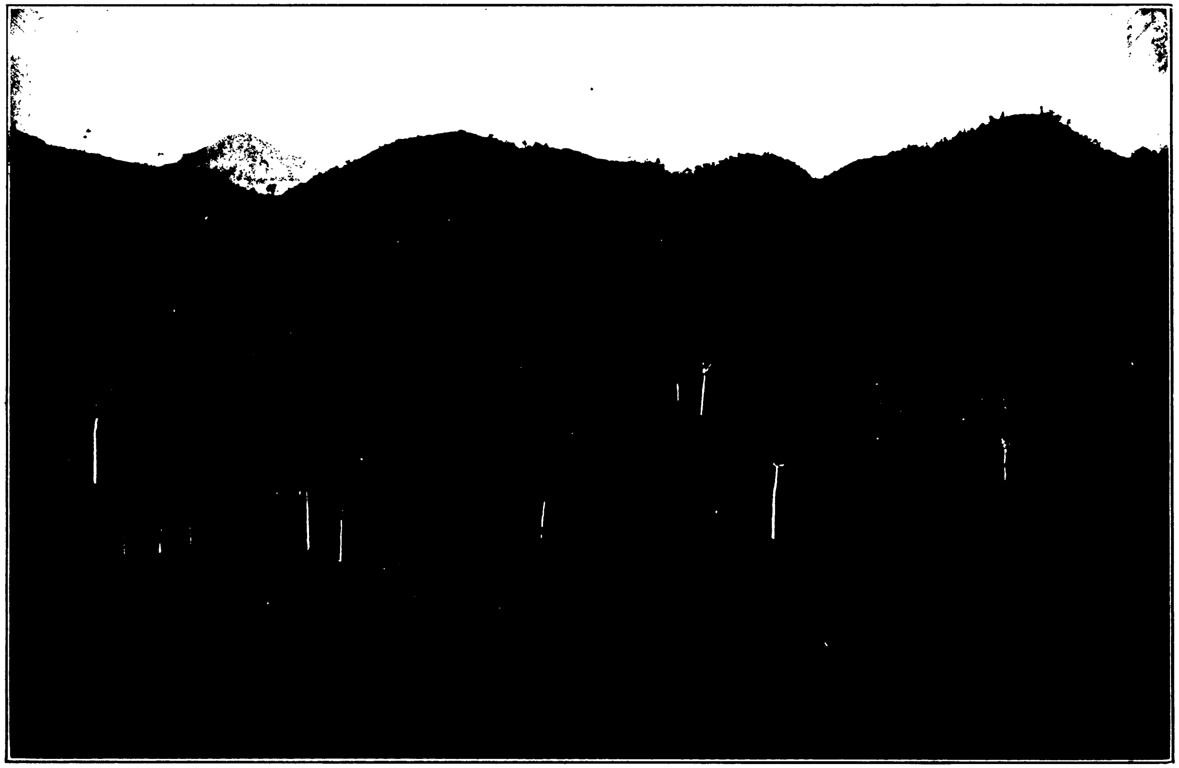
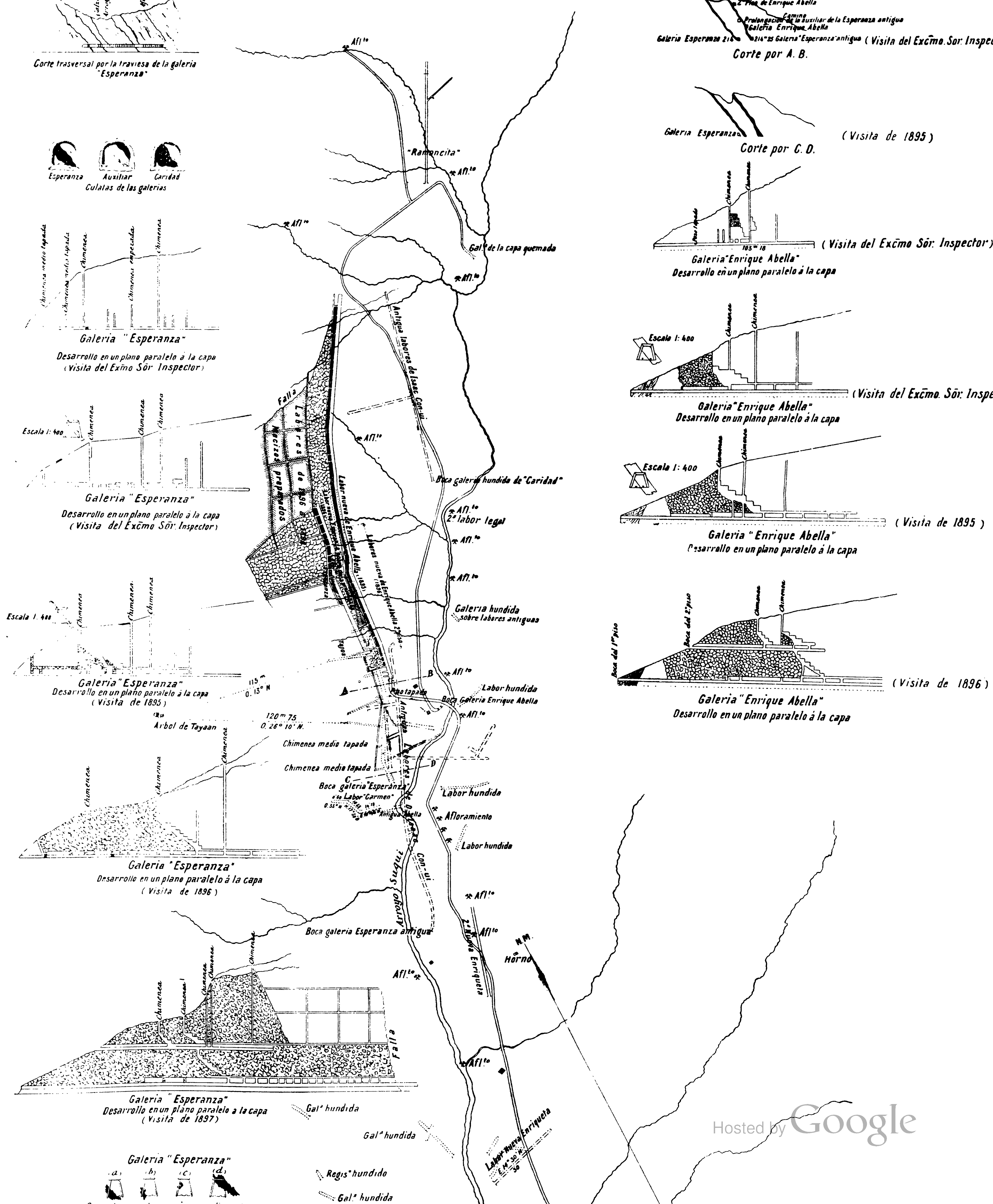


PLATE XI.

PLATE XII.

PLATE XIII.

PLATE XIV.


Corte trasversal por la traviesa de la galeria "Esperanza"
Esperanza
Auxiliar
Caridad
Culatas de las galerias
Chimenea medio tapada
Chimenea medio tapada
Chimenea
Chimenea empezada
Chimenea
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita del Exmo Sôr Inspector)
Escala 1: 400
Chimenea
Chimenea
Chimenea
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita del Excmo Sôr. Inspector)
Escala 1: 400
Chimenea
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Chimenea
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1895)
Arbol de Tayaan
Chimenea
Chimenea
Chimenea
Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1896)
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Galeria "Esperanza"
Desarrollo en un plano paralelo á la capa
(Visita de 1897)
Galeria "Esperanza"
(a)
(b)
(c)
(d)
Afl.to
"Ramoncita"
Afl.to
Afl.to
Gal.a de la capa quemada
Afl.to
Antigua labores del Isaac Con-ui
Falla
Labores de 1896 á 1897
Macizos preparados
Labor nueva de Enrique Abella 1895
Labores nueva de Enrique Abella (1896)
Labor nueva de Enrique Abella 2.º piso
Afl.to
Boca galeria hundida de "Caridad"
Afl.to
2.ª labor legal
Afl.to
Afl.to
Galeria hundida
sobre labores antiguas
Tajos
115 m
0. 13° N
120 m 75
0. 26° 10' N.
A
B
Afl.to
Pozo tapado
Labor hundida
Boca Galeria Enrique Abella
Afl.to
Antiguas Labores de Dazo
Chimenea medio tapada
Chimenea medio tapada
D
C
Boca galeria "Esperanza"
Labor "Carmen"
Antigua Abella
Labor hundida
Afloramiento
Labor hundida
Arroyo Suqui
Con-ui
Afl.to
Afl.to
Boca galeria Esperanza antigua
2.ª Labor Enriqueta
N.M.
Horno
Afl.to
Falla
Afl.to
Gal.a hundida
Gal.a hundida
Labor nueva Enriqueta
E. 14° 30' N.
Regis.o hundido
Gal.a hundida
2.º Piso de Enrique Abella
Camino
Prolongacion de la auxiliar de la Esperanza antigua
Galeria Enrique Abella
Galeria Esperanza 216
216m 25 Galeria "Esperanza" antigua
(Visita del Excmo. Sor. Inspec
Corte por A. B.
Galeria Esperanza
(Visita de 1895)
Corte por C. D.
Pozo tapado
Chimenea
Chimenea
105m 10
(Visita del Excmo Sôr. Inspector)
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
Escala 1: 400
Chimenea
Chimenea
(Visita del Excmo. Sôr. Inspe
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
Escala 1: 400
Chimenea
Chimenea
(Visita de 1895)
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa
Boca del 1.er piso
Boca del 2.º piso
Chimenea
Chimenea
(Visita de 1896)
Galeria "Enrique Abella"
Desarrollo en un plano paralelo á la capa

Oversized Foldout

Oversized Foldout

NOTE ON THE OCCURRENCE OF RHYOLITE IN CEBU.

By HENRY G. FERGUSON.
(From the Division of Mines, Bureau of Science, Manila, P. I.

This rock, collected by Mr. Warren D. Smith during his investigation of the coal fields of Cebu,[1] seemed to be of interest because of the difficulty in determining whether it should be classed as an igneous rock or a siliceous precipitate.

The field relations are not at all clear. The rock occurs in scattered outcrops along the side of the Muao River valley, and near the Bureau of Science bench mark (B+S on the map accompanying Mr. Smith's paper). "Greenstone" and andesite outcrop in the stream bed, and limestone forms the capping of the hill. The contacts are everywhere masked by talus.

CEBU NO. 57.

Hand specimen.—The rock in the hand specimen is whitish, compact and extremely fine grained. It is rather light, four determinations of specific gravity giving: 2.20, 2.26, 2.10, 2.17, average, 2.18. It is sufficiently soft so that it can be scratched with a knife and gives no effervescence with hydrochloric acid. In one part of the specimen there is a well-marked banding which consists of small, slightly darker lines about 2 millimeters apart. A slight tendency to break along this banding was noticed in making the thin sections. A few small grains of magnetite appear in these dark bands. The rock is too fine grained for any other minerals to be identified in the hand specimen.

Another specimen bearing the same number seems to be a more weathered phase of this rock. The color is light green instead of white, as in the unaltered specimen. Beyond this the rocks seem the same. One grain of quartz (about 0.5 millimeter in diameter) was seen in the weathered rock. No banding was noticed. Specific gravity 2.14, 2.15, 2.15.

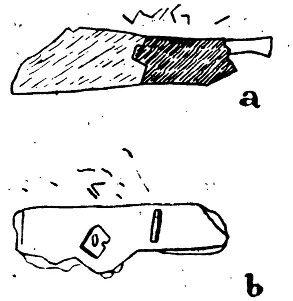

FIG. 1.—*a*, Broken quartz grain; *b*, quartz grain with inclusions.

Microscopic.—The most easily recognizable minerals are quartz and feldspar, occurring in minute grains. The quartz is clear and glassy, the grains as a rule have sharp edges; and apparently, in some cases at least, crystal faces are present. The grains sometimes are broken and occasionally contain inclusions.

The feldspars occur in small, clear, fresh grains. The edges are sharp, but there are no idiomorphic crystals. Only one good determination could be made and this gave basic oligoclase (extinction angle of albite twins, 6° and index of refraction lower than quartz). Probably the majority of the undetermined feldspars are orthoclase.

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[1] Smith, W. D.: *This Journal, Sec. "A," Gen. Sci.* (1907), 2.

Rare grains of epidote occur, generally along the darker bands.

The groundmass in great part is composed of small rods and grains of a practically isotropic mineral with a slight greenish tinge, which, with crossed nicols, gives a very faint, grayish polarization or remains entirely dark. The index of refraction is lower than balsam, hence they are either crystallites or else small rods of opal. They have a wavy, parallel arrangement suggesting flow structure (microfelsitic). Between these rods are aggregates of a mineral having low polarization colors and suggesting chlorite. These sometimes have definite boundaries suggesting the replacement of some other mineral, or possibly only a large interspace between the small rods, or else they fill up irregular interstitial spaces. The polarization is extremely irregular and parts of these aggregates seem isotropic, hence they may represent a cryptocrystalline structure resulting from devitrification.

Small aggregates of a mineral having a high double refraction and resembling either sericite or talc also occur, but these are rare. The banding seems to be due to small patches of nearly opaque brownish matter.

Below is an analysis made by Mr. Herbert S. Walker of this Bureau.

Analysis of Cebu No. 57.

		Per cent.
SiO_2		67.25
Al_2O_3		13.12
Fe_2O_3		.24
CaO		1.23
MgO		1.10
K_2O		4.38
Na_2O		0.59
H_2O	at 11°	6.15
	on ignition	6.11
Total		100.17

The most striking features of the analysis are: (1) The rather large ratio of aluminia to silica, 1: 5.1, which is above what would be expected in a siliceous precipitate; (2) the large percentage of both contained and included water, which would be natural to expect in a chemical precipitate of the nature of a novaculite, having an opaline groundmass, but which, if the rock is igneous, must be referred to devitrification and chloritization of the groundmass, a process which seems hardly far enough advanced to justify such a large amount of water; (3) the extremely low iron content, natural to a precipitate but hardly to be looked for in an igneous rock as fresh as this appears to be; (4) the comparatively high percentage of magnesia; (5) the great excess of potash over soda (7.4: 1 taking percentage values, or 4.7: 1 taking molecular proportions).

In addition to the high water content and the low percentage of iron, there are two other arguments against the rock being of igneous origin. First, the specific gravity (2.18) is abnormally low for an igneous rock, but neglecting all the water this figure would increase to about 2.6, and neglecting only the water lost at 110°, to about 2.4. Second, the quartz and feldspar do not occur in well-formed crystals, but in sharp, angular grains with the quartz often cracked, as if the siliceous waters forming the precipitate had carried a small amount of clastic material. However, fig. 1 and Plate I, fig. 1, show that reëntrants are common and the absence of crystal forms may be explained by magmatic corrosion.

The small isotropic rods may be either casts of, or precipitates around algæ,[2] or they may be crystallites formed in the glassy base of an igneous rock. They seem to bear a greater resemblance to the latter. The banding may be explained as either the result of original deposition or as a flow structure.

Below are tables of analyses of different rocks for comparison and a recast of the analysis of this rock and classification by the quantitative system. I have not been able to find any analysis of siliceous precipitates which at all corresponds to this rock, the nearest being a pulverent sinter, No. 9. It will be seen that the rock agrees closely with Nos. 2, 3, and 4 and falls into the same subrang in the quantitative system.

Comparative table of analysis.

Constituent.	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	76.51	76.41	72.68	74.58	75.20	73.91	99.47	81.95	94.68
Al_2O_3	14.93	14.42	15.62	13.31	12.96	15.29	.17	6.49	
Fe_2O_3	.27	.48	.95	1.31	.37	--------	--------	--------	15.95
FeO	--------	.74	n.d.	n.d.	.27	.89	.12	Trace.	
MgO	1.24	.24	Trace.	.26	.12	--------	.50	.15	Trace.
CaO	1.40	1.43	.63	1.61	.29	.77	.90	.50	1.00
Na_2O	.67	.63	1.17	1.52	2.02	3.62	.15	2.56	.30
K_2O	4.98	3.88	4.30	4.87	8.38	4.79	.07	.65	1.02
H_2O-	--------	1.02	2.90	2.03	[a].58	1.19	.12	7.50	7.43
CO_2	--------	1.40	--------	--------	--------	--------	--------	--------	--------
Total	100.00	100.65	100.02	99.49	100.19	100.46	101.50	99.80	99.97

[a] Loss.

Specific gravity, 2.229.

1. Cebu No. 57, neglecting H_2O.

2. Porphyry, Käserngrat, Windgälle Mountains, Switzerland. Schmidt C.: *Neu. Jahrb.* B. B. (1886), **4**, 432. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 130.)

3. Rhyolite, Nagy-Mihaly, Hungary. Murokozy K.: *Földtani Közlöny* Budapest (1892), **22**, 54. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 130.)

4. Porphyry, Arolo, Lago Maggiore, Piedmont. Ricciardi L.: *Att. Acad. Gioen.* (1885), **18**, 14. (Washington, H. S.: *U. S. G. S., P. P.* **14**, 132.)

$$\text{Nos. 2, 3, 4: Persalane} \begin{cases} \text{Columbare, Alsbachase, Mihalose,} \\ \text{Quarfelic, Domalkalic, Dopotassic.} \end{cases}$$

5. Rhyolite, Silver Cliff, Colo. Cross: *Col. Sci. Soc.* (1887), 229. (Kemp, J. F.: Handb. of Rocks (1906), 28.)

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[2] Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1888), 667.

6. Rhyolite, McClelland Peak, Washoe Dist., Nev. Gooch, F. A.: *U. S. G. S.* (1885), Bull. **17.** (Kemp. J. F.: Handb. of Rocks (1906), 28.)

7. Novaculite, Rockport, Ark. Beachett, R. N., for Griswold, L. S.: Geol. Ark. (1890), **3,** 161. (Kemp, J. F.: Handb. of Rocks (1906), 89.)

8. Geyserite, Yellowstone Park. Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1889), 670.

9. Pulverent Siliceous Sinter, Rotura, New Zealand. Weed, W. H.: *U. S. G. S., 9th An. Rep.* (1889), 670.

Recast analysis of Cebu No. 57, considered as an igneous rock.

Constituent.	Per cent.	Molecular proportions.	Orthoclase.	Albite.	Anorthite.	Corundum.	Hematite.	MgO SiO_2.	Quartz.
SiO_2	76.51	1.275	0.318	0.066	0.050			0.031	0.810
Al_2O_3	14.93	.146	.053	.011	.025	0.57			
Fe_2O_3	.27	.002					0.002		
CaO	1.40	.025			.025				
MgO	1.24	.031						.031	
K_2O	4.98	.053	.053						
Na_2O	.67	.011			.011				
	100.00								

Constituent.	Per cent.			
Quartz	.810	48.60	Q 48.60	Salic 96.59
Orthoclase	.053	29.47	F 42.18	
Albite	.011	5.76		
Anorthite	.025	6.95		
Corundum	.057	5.81	C 5.81	
MgO. SiO_2	.031	3.10	P 3.10	Femic 3.42
Hematite	.002	.32	H .32	
		100.01	100.01	100.01

Class I. Persalane
Subclass I. Persalone
Order 3. (Quarfelic) Columbare
Rang 2. (Domalkalic) Alsbachose
Subrang 2. (Dopotassic) Mihalose.

ILLUSTRATION.

PLATE I, FIG. 1. Photomicrograph of Cebu, No. 57.

PLATE I.

THE OCCURRENCE, COMPOSITION AND RADIOACTIVITY OF THE CLAYS FROM LUZON, PHILIPPINE ISLANDS.

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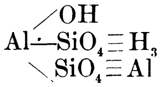
INTRODUCTION.

It seems hardly necessary to define a material of such common occurrence as clay, still at the outset a good definition may more clearly indicate some of its characteristics. Ries [1] says:

> The term clay is applied to a natural substance or rock which, when finely ground and mixed with water, forms a pasty, moldable mass that preserves its shape when air-dried and when burned, changes to a hard, rock-like substance by the coalescence of its particles through softening under the action of heat.

In other words, heat expels the volatile constituents, decomposes many of the finely ground particles and causes the clay to sinter together. Clays under the microscope are shown to be heterogeneous aggregates of hydrous and anhydrous aluminium silicates mixed with a variable quantity of other crystals, mineral particles and impurities in all stages of decay. The fact that silicate of aluminium is so characteristic a constituent of clay is caused by this substance being one of the most insoluble of natural compounds. The size of the crystals or particles varies from 0.01 millimeter up to grains distinctly visible to the naked eye. The varieties of clays are extremely numerous, as they form a continuous series ranging from pure kaolin (kaolinite) down to the more imperfect varieties. This variance is caused by the increasing admixture with kaolin of the common clays, consisting of other silicates of aluminium, the silicates, oxides, carbonates, etc., of iron, calcium, magnesium, and the alkalies, as well as free silica, and often organic matter. Kaolinite itself may only enter into this mixture in a small proportion. This variation is not surprising when we consider the difference in the composition of the original rocks from which the clays are derived. Kaolinite (pure kaolin) is derived from the aluminous minerals, especially feldspar.[2] In practice it rarely exists in the pure state, since decomposition of the pure, parent rock seldom takes place unassociated with that of other minerals, foreign substances in small amount being always mechanically mixed with it; however, because of its almost universal presence, it is often considered the basis of all clay. Kaolinite has the composition: $Si_2O_9Al_2H_4$;[3] or perhaps better  $\mathrm{Al}\begin{array}{l}\diagup \mathrm{OH}\\ -\mathrm{SiO_4}\equiv \mathrm{H_3}\\ \diagdown \mathrm{SiO_4}\equiv \mathrm{Al}\end{array}$ which indicates its relation to the parent mineral[4]; it contains alumina 39.45, silica 46.65, and water 13.9 per cent, respectively.

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[1] *U. S. G. S., P. P.* (1903), 11, 15.

[2] Dana, J. D.: A System of Mineralogy, New York (1900), 319, gives 23 analyses of this species from varied sources. The average is as follows (figures give percentages): SiO_2, 65.06; Al_2O_3, 19.27; CaO, 0.68; K_2O, 10.85; Na_2O, 3.68; Fe_2O_3, 0.16; MgO, 0.07; BaO, 0.05; ignition, 0.08; total, 99.9.

Other clays result not only from the decomposition of feldspar, but from the breaking down of other associated crystalline silicates to which they are related somewhat as kaolin is to the feldspars, and they also contain foreign matter which is mixed with them. Usually these mixtures are so complicated that it is almost impossible to identify them. Just as the clays range from pure kaolin to impure varieties, so in the end, because of a greater proportion of certain of the minerals in the parent rock, the products of decomposition may lose all the characteristic physical features of a clay and thus pass out of this class of bodies entirely.

Clay deposits are usually designated as residuary or sedimentary. As the names imply, these originate from their method of formation, accordingly as this is due to the decomposition of rocks in place or to the resulting decomposition products being transported by the streams and deposited in regular sedimentary beds elsewhere. Kaolin is termed a primary or residuary clay because it is always in the condition of original deposit. This is true of that from Laguna; that is, it is in place but thoroughly leached out. The formation of all clay begins in the same way, by the decay and disintegration of the rock mass. In this Archipelago, where we have no frost during the year, the principal active agents accomplishing this change are water and the sun. Dana[5] says, "Feldspar may be altered through the action of waters rendered acid by the decomposition of sulphides." Such waters filter into the rock, causing partial disintegration, then the drying action of the sun opens cracks for more water to enter and further to attack and break down the mineral grains in the rocks. By means of such infiltrating waters the feldspar of the feldspathic rocks acted on, first loses its lime, which is soon deposited as gypsum (calcium sulphate), next its alkalies as sulphates, and the change finally ends in kaolin or some other silicate of aluminium. In the less resistant portion of the vein the weathering will penetrate to a much greater depth than in the harder parts. An ideal section showing the characteristic breaking down in the formation of residuary clay deposits is as follows:

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[3] Groth, P.: Tabellarische Übersicht der Mineralien, Braunschweig (1898), 137.

[4] Clarke, F. W.: *U. S. G. S. Bull.* (1905), **125**, 28; McNeil, H. C.: *Journ. Am. Chem. Soc.* (1906), **28**, 592.

[5] System of Mineralogy, New York (1900), 320.

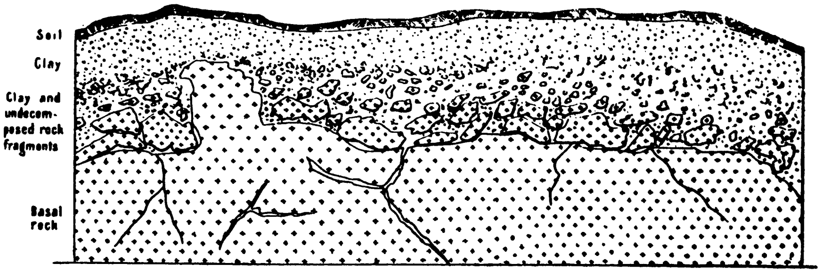

FIG. 1.

One of the best examples known to me where such decomposition is now going on is in northern Rizal along Macoburobod Creek. This stream empties into Poray Creek, San Mateo River, about 10 kilometers above Montalban. Its waters are extremely acid from the decomposition of sulphides. Along its banks is an outcrop of vein material carrying quartz which is characteristically weathered into clay and which shows the whole process taking place in the formation of primary clay deposits. The quartz is unaffected by the action of these waters and remains as grit in the final product. Wherever we have grit in a clay, we can almost invariably attribute it to unweathered particles of quartz which were present in the parent rock. An emulsion of the above clay was filtered through a sixty-mesh sieve. This filtrate, when thoroughly air-dried represents the result of the decomposition in this vein and the product is as follows:

Constituent.	Per cent.
Silica	59.00
Alumina including titanium oxide	16.79
Ferric oxide	7.87
Ferrous oxide	0.42
Lime	0.40
Magnesia	0.00
Alkalies	3.89
Loss on ignition	7.46
Water below 110°	3.18
Sulphur	4.79
	101.80
Less oxygen	1.79
Total	100.01

The formation of a great many of the clay deposits in various parts of the world is attributed to causes almost identical with the above. Bacon,[6] in connection with his investigation of the acid waters of "The

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[6] *This Journal, Sec. A, Gen. Sci.* (1907), **2**, 120.

Crater Lakes of Taal Volcano" has recorded that aluminium hydrate is continually being deposited as a sediment from these lakes. It appears probable that many of the clay beds of the Philippines may have been deposited as a result of the chemical action of similar waters.

As the raw materials vary, so in a similar way do the uses to which clays are put, namely, the manufacture of porcelain, stoneware, earthenware, tiles (drain and roof), terra cotta, sewer pipes, common bricks, "vitrified" bricks for paving, doorknobs, playing marbles, as a filler for paper,[7] a food adulterant, etc. At one end of a series we find the analyses of the fine European porcelain, which is made from practically pure kaolin with admixtures of flint, feldspar, etc., and at or near the other we encounter the crude pottery of the majority of savage tribes, which is usually made from clay very high in iron and containing very little kaolin. If we continue in the direction of silicious dilution, we find the analyses of fire-clay wares and of the so-called "dinas brick" much used for building purposes in many places, for example in western Germany. The latter are pure, crushed quartz, excepting the residue from the milk of lime or clay in the water used for moistening the material before it is molded into the bricks and which is the cementing constituent.

EXPERIMENTAL.

The object of this paper is rather to show in a preliminary way the geologic distribution and quality of clays on Luzon than to pronounce upon their economic values. The chemical composition is the first step toward a complete knowledge of the quality of these materials and I therefore give, in the following table, analyses and tests of a few specimens of the Luzon clays:

Sample No.	DESCRIPTION OF THE CLAYS.
1.	Kaolinite calculated from the theoretical formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$.
2.	Koalin or china clay from Los Baños, Laguna. Approaches closely to koalinite in composition.
3.	Kaolin or china clay from the Vicenti Jesus mine, Laguna. Approaches closely to kaolinite in composition.
4.	Kaolin or china clay, not from Luzon, but from Romblon. It approaches closely to kaolinite in composition and is given for the purpose of comparison.
5.	Koalin or china clay from Laguna Province.
6.	Kaolin or china clay from Los Baños, Laguna Province. Approaches closely to kaolinite in composition.

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[7] Attention has already been directed by Richmond (*This Journal, Sec. A, Gen. Sci.* (1907), **2**, 81) to the probable usefulness of Philippine clays as a filler and a glazing material for paper manufacture. Standards for the purchasing and testing of such filling materials are given by Schacht, W., *Papier Ztg.* (1906), **31**, 4234; *Chem. Abstracts* (1907), **1**, 485.

7. Kaolin or china clay from the west side of Pajo Arroyo, Laguna Province. Approaches closely to kaolinite in composition. Taken from the bottom of a pit 3 meters deep.
8. Kaolin or china clay from Tagonton-Paracale, Camarines. Taken from the wall next to the vein in the San Mauricio mine.
9. Kaolin or china clay from Bauan Solfatara near Point Cazador, Batangas Province.
10. Kaolin or china clay from the east side of Pajo Arroyo, Laguna Province. Taken from the bottom of a pit 3 meters deep.
11. Kaolin or china clay from Bucay, Abra.
12. Kaolin or china clay from Calamba, Laguna Province.
13. Kaolin or china clay from Nasugbu, Batangas Province.
14. Kaolin or china clay from Albay Province.
15. Kaolin or china clay from Ilocos Norte.
16. Kaolin or china clay from Ilocos Norte.
17. Kaolin or china clay from Matiquo, Laguna Province.
18.[a] Kaolin or china clay from Dolores, Abra. Not quite white.
19.[b] Kaolin from Wolfson mine, Laguna Province.
20. Kaolin from the district east of Nasugbu, Batangas Province.
21. Silicious ferruginous kaolin. Exact source unknown.
22. Silicious ferruginous kaolin. Exact source unknown.
23. Kaolin from near Cervantes, Lepanto-Bontoc.
24. White, silicious clay from San Agustin-Magalang, Pampanga Province.
25. Dark, cream river clay from Laguna Province.
26. Gray river clay from Laguna Province.
27. Gray river clay from Laguna Province.
28. Gray river clay from Laguna Province.
29. Gray clay from Clarke's gold mine, Antimok, Benguet. This was refined by making an emulsion, passing through a 60-mesh sieve, and drying at 110° before analyzing. About 39 per cent of quartz and rock fragments were retained on the sieve and discarded.
30. Clay taken from the surface of a deposit of considerable extent which occurs on the banks of the Tinajeros River near Malinta, Bulacan Province. Clay of this quality seems to abound along the route of the Manila and Dagupan Railroad north of Caloocan.
31. Brick clay from Bulacan Province.
32. Common clay from Binangonan, Rizal Province.
33. Clay used in Mandaloyan on the Pasig River, for making brick. Taken from the bottom of a pit about 2 meters deep.
34. Clay from the first hills on the road to Bannangar, Rancherio Tablan, Benguet.
35. Clay used to paint houses. Near Nasugbu, Batangas Province.
36. Clay subsoil.
37. Igorot clay.
38. Igorot clay.

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[a] It may be possible to remove enough iron by washing to make this clay available as an alkaline silicious kaolin. Otherwise it is of low value because the quantity of iron oxide is great enough to give a red body after firing, it is too alkaline for refractory ware and calcareous enough to have a low fusion point.

[b] It may be possible to remove iron from this by selecting and washing and to make it available as a first-class china clay.

TABLE I.—*Analyses of Luzon clays.*

[Figures give percentages.]

Sample No.	Silica (SiO_2).	Alumina (Al_2O_3).	Fluxes.						Loss on ignition.	Water (H_2O) above 110°.[a]	Water (H_2O) below 110°.[b]	Carbon dioxide (CO_2).	Titanic oxide (TiO_2).	Phosphoric anhydride (P_2O_5).	Sulphuric anhydride (SO_3).	Manganous oxide (MnO).	Total.	Total fluxes.
			Ferric oxide (Fe_2O_3).	Ferrous oxide (FeO).	Lime (CaO).	Magnesia (MgO).	Soda (Na_2O).	Potash (K_2O).										
1	46.65	39.45	--------	--------	--------	--------	--------	--------	13.90	--------	--------	--------	--------	--------	--------	--------	--------	0.00
2	44.15	36.54	1.04		0.15	0.00	0.98		13.50	--------	2.64	0.00	1.14	0.00	0.00	0.00	100.14	2.17
3	43.32	[c]41.48	0.32		0.40	0.59	0.38		14.12	--------	0.00	--------	--------	--------	--------	--------	100.61	1.69
4	47.76	[c]37.04	0.75		0.06	0.14	0.52		13.73	--------	0.63	0.00	--------	--------	--------	--------	100.63	1.47
5	42.06	32.04	0.33		0.48	0.32	1.77		[d]20.42	--------	2.08	--------	1.10	--------	--------	0.00	100.60	2.90
6	45.24	37.31	1.00		0.66	0.00	1.69		12.67	--------	1.24	0.00	0.98	0.00	0.00	0.00	100.79	3.35
7	44.30	37.28	0.88	0.64	0.39	0.42	0.49	0.51	12.56	--------	1.60	0.00	1.36	0.00	0.00	0.00	100.32	3.28
8	48.28	34.65	0.92		0.00	0.59	0.40	2.90	10.34	--------	2.10	0.00	0.30	0.00	0.00	--------	100.48	4.81
9	30.30	30.37	0.57		0.00	0.08	3.06	3.02	[d]31.26	--------	0.80	0.00	0.68	Trace.	0.00	--------	100.14	6.73
10	57.68	26.54	0.99	0.05	0.56	0.17	0.54	0.40	10.74	--------	1.87	0.00	1.22	0.00	0.00	--------	100.76	2.71
11	64.57	23.23	0.84		0.00	0.14	0.46	0.00	8.45	--------	2.73	0.00	0.38	0.00	0.00	--------	100.80	1.44
12	61.98	[c]26.22	0.12		0.60	0.72	0.34		10.55	--------	0.00	0.00	--------	0.00	0.00	0.00	100.53	1.78
13	62.74	23.85	1.60		0.15	0.00	1.05	1.56	8.84	--------	0.00	0.00	0.78	0.00	0.00	0.00	100.57	4.36
14	71.16	16.94	0.48		0.57	0.23	0.46	5.64	3.22	--------	1.56	0.00	0.58	0.00	0.00	0.00	100.84	7.38
15	62.26	18.56	0.91		2.97	0.90	1.20	2.16	3.87	--------	7.29	0.00	0.48	0.00	0.00	0.00	100.60	8.14
16	65.75	16.40	1.24		2.55	0.18	1.36	3.65	3.93	--------	4.26	0.00	0.52	--------	--------	0.00	99.84	8.98
17	62.94	[c]22.08	1.36	0.20	0.47	0.77	0.67	4.84	5.42	--------	1.80	0.00	--------	--------	--------	--------	100.55	8.31
18	64.22	15.39	2.52		2.42	1.52	2.32	2.10	5.43	--------	4.39	0.00	0.24	0.00	0.00	--------	100.55	10.88
19	49.95	[c]31.84	3.96		0.36	0.70	0.64		11.90	--------	0.00	0.00	--------	--------	--------	--------	99.35	5.66
20	65.18	19.07	3.93		0.00	0.28	0.56	0.50	9.04	--------	1.10	0.00	0.70	0.06	0.00	--------	100.36	5.27
21	69.08	21.57	2.64	4.10	Trace.	0.04	0.46	2.63	0.00	--------	0.00	Trace.	--------	--------	--------	--------	100.52	7.24
22	74.50	15.17	2.61	2.92	Trace.	Trace.	0.53	2.43	0.00	--------	0.00	Trace.	--------	--------	--------	1.79	99.95	6.06
23	53.63	24.30	5.88		0.31	0.34	0.74	0.98	9.04	--------	4.48	0.00	0.74	0.00	0.00	--------	100.44	8.25
24	67.58	14.20	3.00		2.30	0.27	2.24	2.88	4.60	--------	2.14	Trace.	0.30	0.00	0.00	--------	99.51	10.69

25	59.46	[c]28.00	0.16	1.04	1.29	1.41		7.92	---------	0.00	0.00	---------	---------	---------	---------	99.28	3.90
26	50.00	[c]25.94	8.08	1.16	0.65	4.60		8.64	---------	0.00	0.00	---------	---------	---------	---------	99.07	14.49
27	52.72	[c]26.86	4.10	2.04	2.03	2.57		9.35	---------	0.00	0.00	---------	---------	---------	---------	99.67	11.54
28	52.06	[c]30.02	3.18	0.72	2.04	2.78		8.58	---------	0.00	0.00	---------	---------	---------	---------	99.38	8.72
29	47.22	[c]25.73	9.70	0.60	4.30	0.95	3.24	10.23	---------	0.00	0.00	---------	---------	---------	---------	101.97	18.79
30	47.77	[c]18.73	7.19	1.78	2.06	1.86		13.84	---------	8.42	0.00	---------	---------	---------	---------	101.44	13.04
31	60.24	20.05	4.15	0.47	0.05	3.18	1.44	11.27	---------	0.00	0.00	Trace.	---------	---------	Trace.	100.85	9.29
32	50.81	20.54	7.37	0.91	1.05	---------	---------	8.14	---------	9.98	0.00	1.18	0.00	---------	0.01	99.99	9.33
33	52.53	[c]21.01	8.40	4.04	2.58	2.68		9.08	---------	0.00	0.00	---------	---------	---------	---------	100.32	17.70
34	53.70	26.03	6.53	0.00	0.00	2.20		8.95	---------	2.54	0.00	0.30	0.00	0.00	---------	100.25	8.73
35	57.45	18.08	8.40	1.44	0.00	1.42		8.56	---------	6.08	0.00	0.58	Trace.	0.00	---------	101.99	11.26
36	49.68	18.34	1.70	0.46	0.28	0.00	0.06	14.46	---------	4.95	0.00	0.76	---------	---------	0.00	100.96	2.50
37	54.46	[c]16.77	11.14	0.53	Trace.	Trace.	Trace.	16.81	---------	0.00	0.00	---------	---------	---------	---------	99.69	11.67
38	60.99	[c]17.71	9.53	0.59	Trace.	Trace.	Trace.	10.65	---------	0.00	0.00	---------	---------	---------	---------	99.47	10.12

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[a] Included under loss on ignition which consisted mainly of this factor.

[b] Those samples where the factor is given as zero were dried at 110° before being analyzed. Others were taken as received or were only air-dried.

[c] Includes titanic oxide (TiO_2).

[d] The proportion of water seems abnormal.

In most places, the supply of clay for commercial uses is obtained from surface openings or clay banks and, with the exception of Numbers 8 and 29, this is the case with the specimens given in Table I. Some companies are operating underground works and so obtain a more uniform and purer product.

It is exceptional for clays to be used in their natural state for other than common work, because of the numerous bits of rock which are mingled with their mass. In almost every parent rock there are very hard mineral particles which resist the weathering and remain behind, contaminating the clay. A certain amount of sorting is always necessary. Herein is the justification for printing analyses of the unpurified specimens. It will at once be evident that the deposits will not through sorting become poorer than the published results. For the above reason, a chemical analysis of a residuary clay may not always be reliable as a means of judging its usefulness from the standpoint of the ceramic industries, as it may contain impurities which render it useless in the rough state, but by grinding and decantation it may be separated from its impurities. Ries[8] in summing up the facts obtainable from the ultimate analysis of a clay, gives the following main points:

1. The purity of the clay, showing the proportions of silica, alumina, combined water, and fluxing impurities. High-grade clays show a percentage of silica, alumina and water, approaching quite closely to those of kaolinite.
2. The refractoriness of the clay for, other things being equal, the greater the total sum of fluxing impurities, the more fusible the clay.
3. The color to which the clay burns. This may be judged approximately, for clays with several per cent or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.
4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica the percentage of chemically combined water may be much higher.
5. Excess of silica. A large excess of silica indicates a sandy clay, and if much is present in the analysis of a fire clay, it indicates low refractoriness.
6. The quantity of organic matter. If this is determined separately and it is present to the extent of several per cent, it will require slow burning if the clay is dense.
7. The presence of several per cent of both lime (CaO) and carbon dioxide (CO_2) in the clay indicates that it is quite calcareous.

Several of the above analyses do not to any large degree indicate accidental impurities. A few show minute traces of sulphuric anhydride, probably accounted for by crystals of gypsum which probably could be removed by washing. The iron in most cases is in all likelihood present as the oxide resulting from the decomposition of iron sulphides during the original leaching of the clay material. In rough work it does little harm, and in fine work, if present in particles of any size, it could easily be removed by washing. In some of the Philippine kaolins the iron was observed to be in tiny grains. However, there are many things which are not shown by a chemical analysis. The results of such an analysis are expressed as if all of the metals existed as oxides and the acids as anhydrides. For example, gypsum ($CaSO_4$), calcium carbonate ($CaCO_3$) and siderite ($FeCO_3$) would be considered as present in the form of lime (CaO) and sulphuric anhydride (SO_3), lime and carbonic anhydride or carbon dioxide (CO_2), and ferrous oxide (FeO) and carbon dioxide, respectively. In general, the fusibility of a clay increases directly in proportion to the percentage of fluxing materials which it contains, but there are exceptions depending on the mineral condition of the oxides. If the oxide is present as a carbonate it generally fuses at a different temperature than if it were present in the form of a silicate, and furthermore, the fusibility of the various silicates of the same oxide components vary.

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[8] Wis. Geol. and Nat. Hist. Sur. (1906), **15**, Econ. Ser. **10**, 12.

Some of the commonest minerals in clays are quartz, feldspar, calcite, dolomite, gypsum, apatite, pyrite, other iron ores, mica, talc, serpentine, hornblende, pyroxene, garnet, tourmaline, etc.; these are constituents of the parent rock which have escaped decomposition. With the exception of quartz, the particles are usually too small to be detected by the naked eye so that the "rational analysis"[9] and the mechanical analysis, to supplement the ultimate analysis, are resorted to in order to determine the different percentages of the minerals present. It is not claimed that these are accurate methods, but they are the best yet offered. When a great many different kinds of mineral particles are present in one clay, the methods become extremely complicated and with the common clays are seldom used. For kaolin, where the only constituents are kaolinite, feldspar, and quartz, the "rational analysis" becomes quite simple and especially useful and as most clay workers understand the relative importance of these constituents, when they are determined the behavior of the clay can approximately be estimated.

Research in the direction of mechanical analysis has established methods by which not merely the size of the grains, but also their shape, the specific gravity of the materials, etc., may be determined; these are important factors in establishing the usefulness of clays.

The determination of the fineness of the mechanical division is important, since it gives an idea of the loss when the material is prepared for certain kinds of work. The following data by Mr. L. A. Salinger show the proportion of certain sizes of grains in some of the clays mentioned in this paper. The raw clays were suspended in water, pressed through a 60-mesh sieve, and dried at 110°.

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[9] The actual method is given in almost any text on clay analysis, for example: Ashby, H. M.: "How to Analyse Clay," Chicago (1901), 48.

Number.	Passed through 60 mesh (per cent).	Retained on 60 mesh (per cent).
3	90.2	9.8
12	87.4	12.6
19	95.6	4.4
25	72.2	27.8
26	83.2	16.8
27	72.5	27.5
28	67.0	33.0

I have not been able further to study these properties at this time.

Bourry[10] has formulated a very satisfactory classification of clays, and he gives the following as a differentiation of the principal kinds of kaolin:

> I. *Pure kaolins* do not contain more than from 5 to 6 per cent of silica and 2 per cent of fluxes, the proportion of each of the fluxes taken singly being not more than 1 per cent. They are always brought to this degree of purity by washing, and present themselves in the form of a white powder, occasionally slightly tinted with yellow, gray or red, and very unctuous to the touch. After firing they form a body of milky whiteness. They are used in the manufacture of porcelain and fine faïence.
>
> II. *Alkaline kaolins.*—The only difference between these kaolins and the preceding is that they contain a higher proportion of alkalies, which can mount up to 5 per cent, coming from the mixture of feldspar and mica. In the meantime the proportion of oxide of iron rises sometimes to 2 per cent. They have the same use as the preceding, but it must be observed that a very careful washing results in taking away the greatest part of the alkalies.
>
> III. *Silicious kaolins.*—In these kaolins, hydrosilicate of alumina is mixed in a considerable proportion with quartz in the state of impalpable powder. This content of silica depends greatly on the care bestowed in the washing; it can rise to 20 or 25 per cent. These kaolins furnish a body of small plasticity, and are of a light, granulous texture. They are used in the manufacture of porcelain and certain kinds of faïence, but for bodies which have no need to be very plastic.
>
> IV. *Alkaline silicious kaolins* contain at the same time a considerable proportion of alkalies and of silica, and partake of the properties and uses of the two preceding kinds.
>
> V. *Ferruginous kaolins.*—These kaolins contain a quantity of oxide of iron which is too great to give an entirely white body after firing. When this content is not too high it is utilized in the manufacture of porcelain and faïence of inferior quality. For a greater proportion[11] they can be used in the manufacture of refractory productions, but on the condition that they have not too much alkali.

The clays, the analyses of which are given above, have not been subjected to washing. Such treatment would probably improve and change the classification of some of them. As they are, numbers 1, 2, 3, 4, 5,

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[10] Treatise on Ceramic Industries, London (1901), 59.

[11] Too much iron must be avoided, for it is a fluxing impurity and will lower the fusing point of the clay, especially when in the ferrous condition or in the presence of silicates. Fire clays should not greatly exceed 3 per cent of iron. If the clay contains 5 per cent or more it is suitable only for bricks.

6, and 7 would be classed as pure kaolins; 8 and 9 as alkaline; 10, 11 and 12 as silicious; 13, 14, 15, 16, 17 and 18 as alkaline silicious; and 19, 20, 21, 22 and 23 as ferruginous kaolins.

A satisfactory classification of common clays is more difficult and of less importance; therefore we will group all the remainder, namely numbers 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37 under this class.

Analyses numbers 1, 2, 3, 4, 5, 6 and 7 compare favorably with the analyses of the best quality of kaolin from all parts of the world which are given below:

TABLE II.[12]—*Analyses of the best quality of kaolin from all parts of the world.*

Source.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	Ignition.
England	47.10	37.33	1.11	0.14	0.47	0.20	13.45
Do	43.32	39.74	0.27	0.36	----------	----------	12.67
Do	45.52	40.76	----------	2.17	Trace.	1.90	9.61
America	47.66	37.56	1.39	0.20	0.36	0.25	13.47
Do	46.47	38.82	0.89	0.28	0.25	0.48	13.34
France	48.00	36.00	----------	----------	----------	2.00	13.00
China	50.50	33.70	----------	----------	----------	1.90	11.20
Japan (Schiraye)	47.74	36.68	0.42	0.99	0.30	0.45	13.64
Germany (Dölau)	48.15	37.03	0.60	0.27	0.30	0.82	12.76
Bohemia (Zettlitz)	45.68	38.54	0.90	0.08	0.38	0.66	13.00

The analyses of porcelains from China, Vienna, Meissen, Berlin, Sevres, etc., show a composition of—

Constituent.	Minimum (per cent).	Maximum (per cent).	Average (per cent).	
Silica	53	75	66	
Alumina	18	35	28	
Iron	As little as possible		0.8	
Lime	0	5	1	
Magnesia	0	1.5	0.2	
Potash	0	5	2.5	=4.0
Soda	0	3	1.5	

The water from kaolin passes off at a temperature somewhat above 330° (Hillebrand). If we recalculate the analyses numbered 1, 2, 3, 4, 5, 6 and 7 of Table I to the anhydrous clays as is shown by Table III, we have an average of fluxing materials much below that in the finished product given above. The alumina is higher and the silica lower, and this condition, as no flint has been added, is to be expected. The proper percentages of alumina and silica would be produced by the addition of the latter, and the fluxes would be reduced still lower, or a greater margin for impurities in the flint would be obtained.

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[12] Binns, C. F.: Ceramic Technology, Lond. (1897), 11; Bourry: Loc. cit., 65.

TABLE III.—*Analyses of clays 1 to 7 recalculated to the anhydrous conditions.*

Sample No.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.
1	54.2	45.8	0.0	0.0	0.0	0.0
2	52.5	43.5	1.2	0.2	0.0	1.2
3	50.5	48.2	0.4	0.5	0.7	0.4
4	55.8	43.2	0.9	0.1	0.2	0.6
5	54.2	41.3	0.4	0.6	0.4	2.3
6	52.0	42.8	1.1	0.8	0.0	1.9
7	51.6	43.4	1.7	0.5	0.4	1.1
Average	53.0	44.0	0.8	0.4	0.2	1.1

Some analyses of standard fire clays are given in Table IV and, as will be seen, the analyses of the silicious kaolins numbered 10, 11, 12, 19, 20, 21, and 22 compare well with them.

TABLE IV.[13]—*Analyses of standard fire clays.*

Source.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	Ignition.
England (Stourbridge)	65.10	22.22	1.92	0.14	0.18	0.18	9.86
England (Brierley Hill)	51.80	30.40	4.14	0.40	0.50	1.05	13.11
Do	69.25	17.90	2.97		1.30		7.58
United States	74.93	17.19	0.79	0.29	0.46	1.61	5.44
Bohemia (Zettlitz)	45.68	38.54	0.90	0.08	0.38	0.66	13.00

Analyses of the products of primitive peoples are given by Binns[14] from which the following have been selected:

TABLE V.—*Analyses of the products of primitive peoples.*

Material.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Ignition.
Scandinavian pottery	63.90	12.76	10.24	1.04	0.52	11.00
Peruvian pottery	67.04	10.83	10.17	3.24	0.28	8.07
Etruscan pottery	64.00	12.51	8.00	3.51	1.83	10.15

The loss on ignition demonstrates that these products have been fired at a very low temperature. They are given in order to show the comparison with the clay materials used by the Igorots. Analyses numbered 36 and 37 of Table I are only slightly better than the material the analyses of which are given in the above table. Practically all of the native pottery, cooking pots, "pelones," etc., outside of Manila are made from ordinary brick clay.

Chemical analyses of clays to be used for commercial purposes, are fundamental and at the outset necessary, for without them the reconstruction of the final material would be next to impossible. Because of the variation needed in making different wares it is seldom that a single clay is used for the purpose of manufacture; as a rule, several are mixed together. One kind of clay by judicious admixture of other materials is often adaptable to the manufacture of several varieties of wares. A practical potter, if he has a complete knowledge of the chemical composition of a clay, is able to mix different varieties and materials to suit a given purpose; that is, a chemical analysis shows him what ingredients must be added or removed to give a desired result. In itself, a chemical analysis does not show whether or not a clay is useful for a given purpose, for of the impurities in a clay some are easily melted, others are infusible, some are plastic and others are brittle, and slight differences in the plasticity, tensile strength, shrinkage, fusibility, color, etc., which are not controlled by the chemical composition, may very largely affect the commercial value of a clay.

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[13] Cf. Bourry, 65.

[14] Loc. cit., 16.

Plasticity, that common property of all clay to form a moldable mass when wet, varies with different samples, forming an entire series, from those of low to the ones of very high plasticity. This property can not be inferred from the chemical analysis. Up to a certain point there is a coincidence of plasticity and bonding power and several of the other physical properties stand in close relation to the former. Manufacturers, as a consequence, carefully study the means of changing the degree of plasticity of clays; those which are commonly known are: The reduction by adding sand or less plastic clay, while materials of too low plasticity may often have this property increased by washing and thereby removing a part of the sand. Rohland [15] gives the following:

> A. The ways of increasing the plasticity of clays: First, by contact with spring or river water, by means of which colloids are formed by hydrolysis. Thus silicic acid, aluminium, and iron hydroxides are produced. The action is expedited by fine grinding. Because the hydroxyl ions resulting from the hydrolysis tend to decrease the plasticity, pure water is not suitable for the above purpose, but owing to the acid fermentation of the organic constituents present, spring or river water, assisted by the organic matter of the clay or substances added intentionally, neutralize the action of the hydroxyl ions. Second, by lowering the temperature which has also to do with the colloids of clay. The effect is a very slow one. Third, by the addition of colloids and organic substances like dextrin, tannic acid, catechu, etc.
>
> B. The ways of decreasing the plasticity, as: First, by the addition of hydroxyl ions, lime water being the cheapest reagent for this purpose. If the concentration of the hydroxyl ions of the lime water is too low for some clays, it may be increased by the addition of sodium hydroxide solution or any strong base combined with a weak acid. The latter class is represented by phosphates, silicates, etc. Neutral salts like sodium chloride, Glauber's salt, magnesium chloride, etc., appear to be indifferent. Borax weakens the effect of the hydroxyl ion and potassium carbonate strengthens the action. Second, by raising the temperature. Just as gelatin, agar-agar, etc., liquefy on heating to a certain

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[15] *Sprechsaal* (1906), 42, 1371; *Chem. Abstracts* (1907), 1, 90.

temperature, so increased temperature causes clay to "run" and hence decreases plasticity. It appears likely that the organic constituents of clay cause this liquefaction as soon as a certain limiting temperature has been exceeded. The increase in temperature may be brought about mechanically by stirring.

There is no uniform way of determining plasticity. Some workers employ Bischof's method of forcing the moist clay through a die and measuring the distance it projects; others use the Vicat needle,[16] the method of Grout,[17] etc. There is a certain degree of relationship between the plasticity and the amount of water necessary to be added in order to form a workable paste. A fine-grained clay usually requires more water and as a rule is more plastic than one which is coarse. In the experiments recorded in Table VI water was added until the Vicat needle showed normal consistency, the water being afterwards determined by allowing the sample to air-dry.

Tensile or breaking strength is the resistance to rupture which is offered by the air-dried clay. This is an important factor to be determined in order to know the amount of nonplastic material that can safely be added and the sample still resist the shocks and strains in handling to which it is always subjected in the process of manufacture. This may be determined on any standard machine such as is used for the same purpose in cements. In carrying out the test the tempered clay is molded into briquettes, just as is the case with cement, the briquettes having a cross section of 6.45 square centimeters (1 square inch) when molded. They are allowed to dry, first in the air, then at 100°; then placed in the testing machine and a uniformly increasing load gradually applied so as not to produce a shock, until they break. Care must be exercised in placing the briquettes in the machine to prevent all cross strains from improper centering, and from other causes. Theoretically, a briquette should break across its smallest cross section, but failure to take any of the above precautions may result in anything but this.

Shrinkage is of two kinds—that which occurs in the air after the clay has been molded in a wet condition and that which takes place during the operation of burning. Both of these quantities vary greatly and are very useful in estimating the value of the raw material. The decrease of volume in the air is due to the drawing together of the particles, when the water added to afford a workable mass evaporates. Even in the same clay, this factor is often somewhat variable in proportion to the pressure given the material in molding. The amount of shrinkage of a clay upon burning depends not only upon the quantity of volatile constituents such as organic matter, water of constitution, carbon dioxide, etc., but also upon the texture of the clay and the temperature at which it is burned. Some clays containing high percentages of calcium and magnesium carbonates, even expand during certain stages of the process, although they show normal shrinkage at other periods during the burning. Many clays shrink to such an extent that they warp, crack, or blister when burned. When the fire shrinkage is large, other substances of small or no fire shrinkage must be added. It is also necessary to know the air shrinkage in order to estimate the size of a mold necessary to give a finished product of given dimensions.

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[16] Langenbeck, Karl: Chemistry of Pottery, Easton, Pa. (1895), 19.

[17] *Journ. Am. Chem. Soc.* (1905), 27, 1037.

The shrinkages expressed in Table VI are given in per cent of the length of the briquette when freshly molded. The clays were all burned at a uniform temperature of about 1,100° C. (slightly above the melting point of gold), which is well above that at which all water of constitution passes off.

Fusibility is either increased or decreased by each constituent of a clay. Fire clay is practically pure aluminium silicate together with silica, and it will bear intense heat without melting. The presence of different quantities of iron alone varies the fusibility of the clay and therefore the use which can be made of it. The less the iron content the more refractory the clay. Other common fluxing materials are magnesia, lime, sodium and potassium compounds, and I have arranged them in the order of their fluxing power. The presence of any of these with the iron helps to form a flux and greatly to lower the fusion point. For example, if more than 2 or 3 per cent of lime or potash is present in a clay, good brick will not result as these substances cause the bricks to run into glass while they are being burned. The fusion point of a clay can best be determined by means of a pyrometer. It may also be satisfactorily judged by comparison with test pieces of known composition (standard Seger cones),[18] etc. The elaborate work on the composition and fusing point of Seger cones will be of assistance in deciding the fusibility of a clay from its analysis, as well as in actual comparative tests made by placing cones and clay side by side in the furnace. Cone number 1 melts at 1,150° and cone number 20 at 1,530°. The difference between any two successive numbers is 20° and the highest number is 36; this cone is composed of absolutely pure kaolin. The temperatures usually obtained in porcelain furnaces lie between the melting points of cones numbered 1 and 20.[19]

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[18] Reis, H.: *U. S. G. S., P. P.* (1903), 11, 24; Bourry, E.: *Loc. cit.*, 396.

[19] The following data taken from Bourry's "Treatise on Ceramic Industries" give an idea of the numbers of the Seger cones which are used in various potteries:

Muffle firing for decoration	0.022 to 0.010
Burning fusible bodies	.015 to .01
Burning slightly fusible bodies	1 to 10
Stone ware burning	5 to 10
Burning the body for fine faïence	3 to 10
Burning the glaze for fine faïence	.010 to .01
Burning fire-clay ware and porcelain	10 to 20

The tests from 20 to 36 are used only in experiments for fusibility. The work of Simonis, *Sprechsaal*, 6, 71, *Chem. Abstracts* (1907), 1, 2166, shows that cones 20–25 melt within 18° of each other and that their use seems unnecessary.

The highest constant temperature obtainable in this country is at Zobel's pottery kiln in San Pedro Macati. In it a temperature of over 1,300° is attained, which is about the same as the highest temperature attainable in the muffle furnace of this Bureau. The kiln was placed at my disposal for experimental purposes and the temperatures of fusibility recorded in Table VI were determined there by comparison with standard cones and the temperature confirmed thermoelectrically. The fusing points marked *b* either lay above the temperature obtained with the furnace used, or a sufficient quantity of the sample was not at hand and therefore they were estimated from their analyses given in Table I, by comparison with a table of Seger cones and the fusion points actually determined, and by our general knowledge of fluxing materials.

The color of a raw clay is usually due to the presence of organic matter or of iron. In general, the former imparts a gray or black and the latter a buff or red color.

The color of a burned clay to a large extent depends on the proportion of iron and the state of its oxidization. Its presence makes the resulting product buff-brown or red. The more iron the clay contains, the deeper the red color. A quantity of iron as small as 1 per cent may impart a slight, yellowish tint. Clay which bears practically no iron burns white. In many cases the oxides of other metals are present and these often modulate the effect of the iron. The intensity of the color depends also on the temperature and the supply of air entering the kiln; in some cases it is possible to vary it from pink to reddish violet by changing these conditions and influencing the degree of oxidization. Sometimes these means are used to produce a standard or varied shade in wares. In terra cotta, especially, a certain percentage of iron is sought to give the finished product a definite and desired color. A certain manufacture is often known by the particular shade of the finished product. Titanium [20] renders clay yellow on burning. This is visible only when the material has a very low percentage of iron; when more iron is present the yellow is entirely obscured.

Below are given some physical properties of Philippine clays, including the plasticity, breaking or tensile strength, the shrinkage from the plastic condition in the air and with burning, and color.

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[20] Attention is directed to the fact of the usual occurrence of titanic oxide in Philippine clay (see Table I). Its determination has not been carried out in every case, but not a single analysis has been made where it was not present and it usually occurs to the extent of from 0.4 to 1.3 per cent.

I have recently been interested in the titaniferous sands of these Islands and find them of almost universal occurrence. The commonest titaniferous minerals in these are ilmenite and rutile. These minerals occur only in small quantities in the rocks from which the sands are derived, for the sands represent large concentration; however, their universal distribution clearly indicates that they are the probable source of the titanium in clay.

TABLE VI.—*Physical properties of Philippine clays.*

Clay number.	Water added to give a workable paste (per cent total weight).	Tensile strength (pounds per square inch).		Shrinkage (per cent).			Fusibility.	Color.	
		Air-dried.	Burned.	Air.	Fire.	Total.		Air-dried.	Burned.
([a])	14.0	181	Medium	7.5	------	------	1330	Light gray	Pale violet gray.
2	31.6	------	Low	3.6	4.7	8.3	[b]1720	White	Very light grayish white.
3	31.1	11	do	4.2	4.4	8.6	[b]1740	Cream	Rosy cream.
4	------	------	------	------	------	------	[b]1760	------	
5	30.4	------	Low	5.2	6.8	12.0	[b]1680	White	Creamy white.
6	33.6	------	do	3.6	4.0	7.6	[b]1650	do	White.
7	31.6	------	do	2.0	6.0	8.0	[b]1650	do	Pinkish white.
8	27.9	63	do	4.8	1.9	6.7	[b]1560	Creamy white	Creamy white.
9	21.9	43	Medium	3.2	13.6	16.8	[b]1450	Light buff	Pale lilac and rose.
10	38.6	------	Low	3.2	------	------	[b]1690	Creamy white	Light cream.
11	31.3	63	do	8.2	0.9	9.1	[b]1760	White	Creamy white.
12	36.0	12	do	1.5	4.1	5.6	[b]1730	do	White.
13	24.0	46	do	4.7	0.4	5.1	[b]1590	Bluish white	Pale lilac.
14	------	------	------	------	------	------	[b]1410	------	
15	------	------	------	------	------	------	[b]1350	------	
16	------	------	------	------	------	------	[b]1300	------	
17	------	------	------	------	------	------	[b]1350	Creamy white	
18	32.2	72	High	1.1	14.7	15.8	1150	Smoky creamy white.	Pale reddish chocolate.
19	35.5	52	Medium	3.7	3.4	7.1	[b]1510	Bluish white	Yellowish pale violet.
20	23.0	45	------	4.8	0.4	5.2	[b]1535	do	Very pale violet.
21	------	------	------	------	------	------	[b]1420	------	
22	------	------	------	------	------	------	[b]1490	------	
23	21.0	67	------	3.2	3.1	6.3	[b]1360	Grayish white	Pale gray lilac.
24	27.6	58	High	2.0	16.7	18.7	1200	Creamy white	Very pale reddish chocolate.
25	24.0	160	Medium	11.5	6.1	17.6	[b]1500	Dark cream	Violaceous pale gray.[c]
26	25.5	171	do	11.6	5.1	16.7	1350	Bluish gray	Gray lilac.[d]
27	20.0	187	do	8.2	4.4	12.6	1350	Light gray	Pale gray lilac.[d]
28	23.8	176	High	10.0	3.8	13.8	1330	Light slate gray	Reddish gray lilac.
29	------	------	------	------	------	------	1310	Light gray	
30	------	------	------	------	------	------	[b]1150	Light ocherish gray.	
31	------	------	------	------	------	------	[b]1290	------	
32	26.5	131	Medium	12.5	11.9	24.4	1330	Brown	Reddish chocolate.
33	------	180	High	10.0	1.8	11.8	1200	Light brown	Do.
34	24.6	78	Medium	4.4	9.8	14.2	[b]1370	Buff	Do.
35	24.3	77	Below medium.	------	------	8.0	[b]1270	Dark ocher	Very pale reddish ocher.

[a] Given on page 415.

[b] Estimated.

[c] Some pieces decrepitate upon burning.

[d] Decrepitates very badly upon burning.

It is realized that the field for the ceramic industries is very large and that the contribution of the data which I have collected is of small significance, but since all information regarding Philippine clays is meager, these analyses may be of service in indicating the quality and the extent of the distribution.

McCaskey[21] in discussing the occurrence of clay in the Philippine Islands says:

> White clays, or kaolin, have been found in the Provinces of Abra, Camarines, Ilocos Norte, Antique, Benguet, Cagayan, Isabela, Laguna, Marinduque, Masbate, Pampanga, Pangasinan, Albay, Romblon, and Zambales.
>
> Red clays, from which natives make large amounts of pottery for local use, are found in almost every province in the Islands.
>
> Fire clay has been found in the coal beds and may afford a profitable industry in the future.
>
> Red bricks are made in large quantities in Bulacan, Capiz, Rizal, Ilocos Norte, Isabela, Marinduque, Masbate, and Pampanga.

Not much information is available regarding the magnitude of these deposits in Luzon; but the geologists report some of them to be large. Ickis[22] says:

> In the Pajo Arroyo about 3 miles west of Los Baños and 1½ miles from the lake occurs a deposit of white clay which at present is being mined, sacked, and carried on the backs of natives to the Los Baños road; thence it is carted to Los Baños and shipped to Manila. All of the clay contains brown, iron-stained streaks, but below the first 2 feet the percentage of iron-stained material is very small. For a depth of 2 feet the clay contains some organic matter, besides a considerable percentage of iron, and is very plastic. The firm, white clay below varies greatly as regards plasticity. Most of the material exposed in the various holes possesses this valuable quality to a limited extent only, but one pit on the west side of the arroyo furnishes a pure, white clay highly prized by the workmen, which is much more plastic. Sample number 10, taken from the largest pit on the east side of the arroyo, represents the first class while number 7 is a sample of the more plastic clay.[23]
>
> It was impossible for me to determine the extent of this bed of clay, owing partly to the limited time at my disposal and partly to want of exposures or extensive development work, but from surface indications the deposit seems to be large.

A study of Table III plainly shows that if deposits of sufficient magnitude warrant the establishment of porcelain factories, these kaolins can be recomposed by judiciously selecting and combining the clays with other materials to give the desired results. For example, if 70 per cent of specimen number 2, 20 per cent of feldspar ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$) and 10 per cent of flint (SiO_2) were to be mixed together, and the result calculated, which would be obtained after the expulsion of the water and other material lost on ignition, we would obtain the following composition:

Silica.	Alumina.	Iron.	Lime.	Magnesia.	Alkalies.	Titanic oxide.
58.3	34.8	0.87	0.13	0.0	4.90	1.07

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[21] *Fifth Annual Report of the Mining Bureau*, Manila (1904), 35.

[22] *Sixth Annual Report of the Mining Bureau*, Manila (1905), 58.

[23] The analyses are given under the same numbers in Table I.

which is almost identical with that of Meissen porcelain, given by Binns [24] as follows:

Silica.	Alumina.	Iron.	Lime.	Magnesia.	Alkalies.
58.5	35.10	0.80	0.30	Trace.	5.00

The common clays of Luzon are already used in several places in the manufacture of brick and crude pottery. For example, the brick-kilns at Mandaloyon and the one near San Pedro Macati, on the Pasig River near Santa Ana, each of which employs from ten to twenty laborers, turn out from one to three thousand bricks a day per kiln. Sample number 33, Table I, is an analysis of the clay used in Mandaloyon. No sand is added to it before molding, but the whole bank is broken down, mixed by the tread of carabaos, and used for the bricks. This makes the composition slightly different from the analysis given, but tests of the shrinkage and tensile strength show that its physical properties remain almost unchanged.

At present there is no fine pottery being made on this island. There is a factory near Manila which manufactures plates, cups, saucers, bowls, etc., and for these about 20 tons of the good Laguna kaolin are used every year.

The kaolin from Calamba employed in this pottery is too plastic when used alone, so it is recomposed by mixing with two varieties from Bulacan and Ilocos Norte Provinces, respectively. Experiments are now being made with Mariquina clay. The quartz used is picked from the gravel which is being dredged from the Pasig River near by; the asbestos which is placed in a layer between the plates in burning is from Zambales Province. It is of very poor quality, probably a much better variety may be obtained from Ilocos Norte.[25] The ware is dipped once for the siliceous glaze before it is burned. The breakage is small, not exceeding 2 or 3 per cent during the molding, drying, etc., and 4 or 5 per cent during the burning. Some of the ware is decorated in simple designs. It is difficult to describe the final product, which is quite similar to the English Dolton ware. This establishment employs eight men and the output is about 5,000 pieces per month. Formerly this ware had a large sale in Manila, but now is sold mostly in the provinces. There are two men still engaged in bringing kaolin from Laguna Province to the Manila market. The two sources are near Calamba and Los Baños from which are brought about 75 or 100 tons per year, respectively, it sells at wholesale in Manila for from ₱23 ($11.50, United States currency) to ₱32 ($16, United States currency) per ton. It is usually bought in 10-pound balls and finds its principal purchasers among the Chinese of Binondo, who make of it a sort of whitewash. The retail price varies with the supply from 25 centavos (12½ cents, United States currency) a ball in the dry season to 40 centavos (20 cents, United States currency) during the rains, the higher price being due to the difficulties encountered in transporting the clay to market. These may be judged from an account of the working of Calamba clay given by Señor de la Rosa. He says that the clay is dug and carried on the backs of natives about 7 or 8 kilometers to the barrio of Bucal where the women make it into balls. When 500 to 1,000 of these are ready they are loaded into *bancas* and taken about 4 or 5 kilometers to Calamba where they are transferred to a casco and brought under tow to Manila.

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[24] Ceramic Technology, London (1897), 19.

[25] Smith, W. D.: *This Journal, Sec. A, Gen. Sci.* (1907), 2, 145.

The depth of the kaolin at Calamba has not been investigated, for after digging down about 2 meters it becomes too hot [26] to allow further penetration and then the washing of the rain fills up the hole. The superficial exposure is about a hectare. This kaolin has been used to some extent as a fire clay, for example, to repair the brickkiln at San Pedro Macati and the furnace of the glass factory. Señor Varcena at the school in Sampaloc has made some fire bricks and crucibles of good appearance from this clay.

As the price of building materials of all kinds is very high and shows little sign of decreasing, the demand for clay products of this nature is sure to increase. Many which are now in use can be replaced entirely by manufactures from local clays, if their preparation is taken up and placed upon a commercial basis. The tests of clays here reported should aid in the selection of suitable localities and in the finding of proper material for the development of these industries.

RADIOACTIVITY.

In carrying out a series of experiments to ascertain the cause of the abnormal amounts of radioactive emanations contained in the air of cellars and caves, it was demonstrated by Elster and Geitel [27] that such emanations were not of spontaneous origin, but rather came from the soil and clay. They proved [28] that the air removed by simple suction from the soil was charged with active emanation and that its activity actually exceeded that of the air of cellars and caves. This activity is either a universal property of the air of the ground independent of the nature of the soil, or it is the result of a certain amount of primarily active substance contained in the material of the soil itself. Elster and Geitel have shown the latter assumption to be the only tenable theory. They found [29] that clay dug from their garden, introduced into their apparatus, after three days had reached a constant maximum value of about three times the normal. They considered that most of the

[26] The Los Baños springs are thermal.

[27] *Chem. News* (1903), **88**, 29.

[28] *Phys. Ztschr.* (1902), **3**, 574.

[29] *Ibid.* (1903), **4**, 522; *Chem. News.* (1903), **88**, 30.

conductivity observed in the gas was due to a radioactive emanation which diffused from the clay into the air in the vessel. They [30] say:

> It did not matter in this experiment whether the earth was in the moist condition in which it was removed, or whether it was introduced underneath the bell-glass after protracted drying; after the lapse of eight months no decrease of activity was apparent in the material.

In another experiment several substances were placed one-half meter in the earth, after four weeks they were dug up and the potter's clay, which in the beginning was inactive, was unmistakably active. The other substances used were still inactive. This shows that clays also have induced activity. Elster and Geitel found at different places considerable difference in the radioactivity of clays, it being invariably less near the sea.

The conductivity in the gas above the clay in the case already cited has been calculated [31] to be the same as that produced by the emanation from 7.10^{-10} grams of radium. Taking the density of clay as 2, this corresponds to about 10^{-13} grams radium per gram of clay. This has been calculated to be not greatly different from the amount of radium necessary in the earth to emit sufficient heat to compensate for the loss by conduction and radiation. On the basis of this Rutherford [32] expresses it as his opinion that the present rate of loss of heat of the earth might have continued unchanged for long periods of time.

I have examined several different specimens of the clays of Luzon, namely, numbers 8, 12, 32 and 33, by means of the leakage apparatus and all efforts failed to discover a trace of primary radioactivity in the material. The apparatus was of the general type of instrument used by Elster and Geitel,[33] Mache and Meyer,[34] Bacon[35] and other workers in their investigations of the radioactivity of ordinary materials. (See Pl. I.)

Three methods of determination were used in each case. One portion of the clay amounting to 10 grams was put immediately in the measuring chamber and the fall of the charged gold leaf observed for a period of hours; another was digested with acid in an Ehrlenmeyer flask, for some time tightly stoppered and allowed to stand. A third portion was fused with sodium carbonate, slaked in water, neutralized with hydrochloric acid and tightly stoppered in an Ehrlenmeyer flask. After one month these Ehrlenmeyer flasks in turn were connected in circuit with the apparatus and air was sucked through the solution so that any emanation would be drawn with it into the apparatus. In all cases excepting one, the air leak was perfectly normal for a period of hours, being identical with that produced by the natural activity of the air. In the first experiment with clay number 32 the conductivity was observed to be nearly double for a period of two hours, when the increase fell away.

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[30] *Chem. News* (1903), **88**, 30.
[31] Rutherford, E.: Radioactivity, Cambridge, Eng. (1905), 507.
[32] *Ibid.*, 496.
[33] *Phys. Ztschr.* (1904), **5**, 321.
[34] *Monatsh. f. Chem.* (1905), **26**, 596.
[35] *This Journal* (1906), **1**, 435.

The apparatus was sufficiently sensitive as is shown by test experiments with a sample of black uranium oxide (Kahlbaum) and one of pitchblende from Joachimthal which contained 26 per cent of uranium. One gram of the oxide was in turn uniformly spread over the bottom of platinum containers of various sizes, from a platinum crucible the bottom of which is 2 centimeters in diameter to a dish 4.5 centimeters in diameter and put immediately in the electroscope jar. The rate of fall in these was from 80 to 107 scale divisions per minute, 4,800 to 6,420 per hour, depending on the thinness of the layer of powder. Similarly, the rate of fall for one gram of the pitchblende varied from 100 to 203 scale divisions per minute, 8,000 to 12,180 per hour, depending on the spreading. The larger of these rates in each case is about the same as that obtained by Bacon[36] who used a dish of 4 or 5 centimeters diameter as the container in his experiments.

These numbers are not necessarily the maximum value because of the unavoidable absorption of the emanation at the surface of the powder, but with reasonably large spreading surface and working under constant conditions, the results are roughly comparable. The greatest activity of pitchblende yet observed is about five or six times that of uranium, and when they are considered with reference to the uranium content, approximately, that is the relation which exists between the above samples. By dissolving a mineral and then setting it aside in a closed vessel, the amount of emanation present reaches a maximum value after a month's interval. This was done with a gram of the pitchblende, the emanation being drawn into the apparatus by sucking air through the solution and a rate of fall of 640 scale divisions or 38,400 per hour was obtained as the average of eight closely agreeing readings under different chargings. The apparatus therefore was so sensitive that this pitchblende gave a rate of fall of the gold leaf more than 12,000 times as fast as that produced by the leakage through normal air.

From the work of Elster and Geitel the conclusion may be drawn that no primary radioactivity can be present in the above samples of Philippine clays, since they suffered no diminution in eight months. If our clays contained primary radioactive bodies this effect would have been noted since the samples were all investigated in less than eight months from the time they were taken. An extremely small amount of induced radioactivity was observed in clay number 32, while a certain amount might have been lost from the other samples during the time intervening between the taking of the sample and its examination in the laboratory. However, it seems more probable that there may be practically no radioactive bodies in these Islands, for two reasons, first, according to Elster and Geitel, very little radioactivity exists near the sea and, second, matter dissociates under the influence of radiant energy. The tropical sunlight affords opportunity for the maximum effect of the latter. Le Bon[37] calls attention to the fact that radiant energy falling upon matter causes it to dissociate, and if it is of sufficient intensity to heat the substance it also causes an expulsion of a small quantity of the radioactive elements produced by the dissociation. The action of the intense tropical sunlight for centuries on the various deposits occurring here may be accountable for the almost entire absence of radioactivity in these Islands. In support of this suggestion attention is called to the work of Ramsay and Spencer[38] where the "fatigue of metals," a perhaps comparable phenomenon, is produced by the action of intense light. It should also be remembered that Bacon[39] found no radioactivity in the waters of the crater lakes of Taal Volcano.

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[36] *Ibid, Gen. Sci., Sec. A* (1907), 2, 124.

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[37] *Compt. Rend. Acad. d. sc.* (1906), **143**, 647.

[38] *Philosophical Mag.* (1906), **12**, 402.

[39] *This Journal, Gen. Sci., Sec. A* (1907), **2**, 115.

ILLUSTRATIONS.

Plate I. Leakage apparatus used in examining several different specimens of the clays of Luzon (Cf. p. 433).

Fig. 1 (in text). Section showing the characteristic breaking down in the formation of residuary clay deposits.

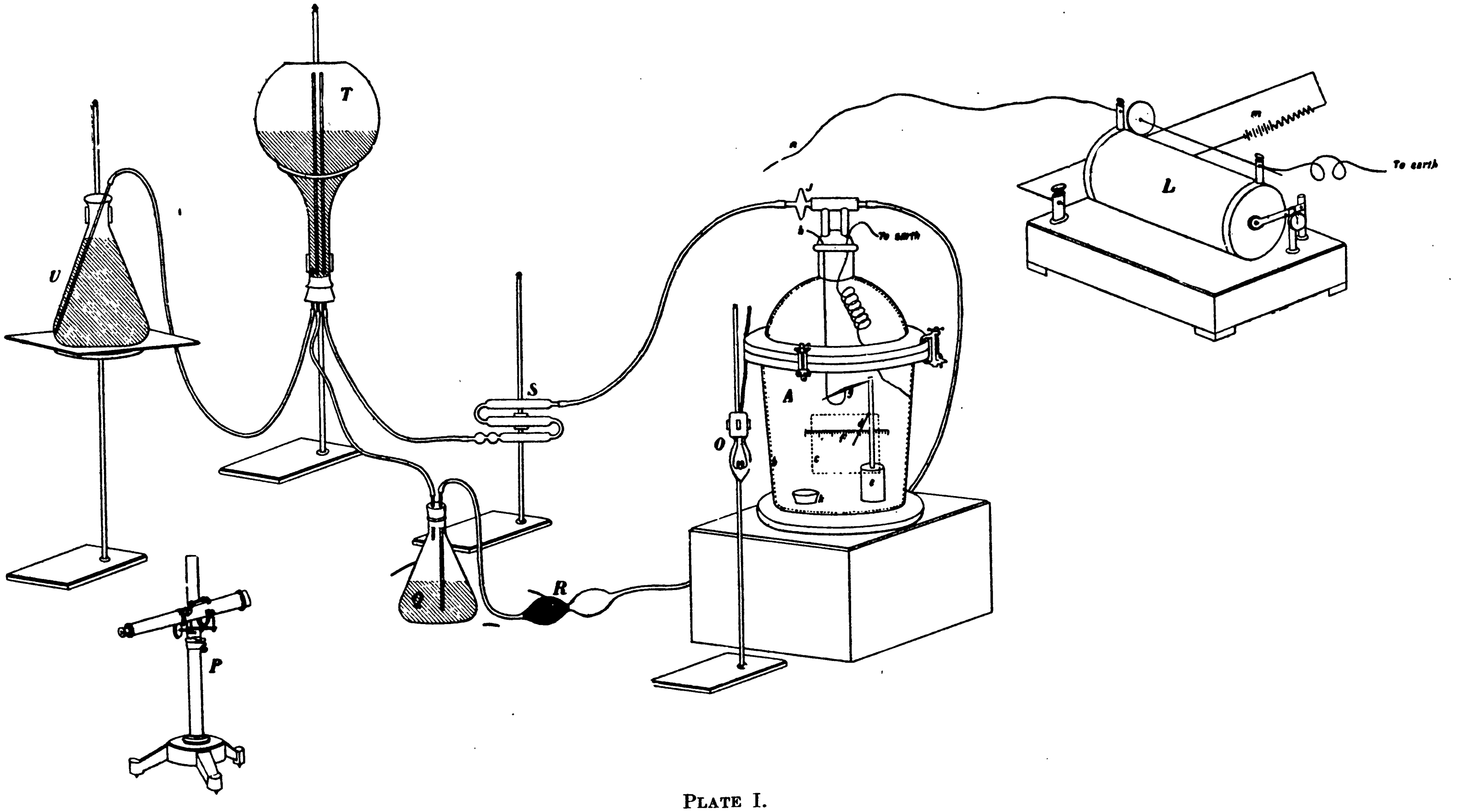

PLATE I.

LEAKAGE APPARATUS USED IN EXAMINING SEVERAL DIFFERENT SPECIMENS OF THE CLAYS OF LUZON.

A, An anaërobic jar fitted up for the measuring chamber. *b*, Tin-foil lining connected to earth. *c*, Observation hole in the lining. *d*, Gold-leaf electroscope. *e*, Insulating base. *f*, Scale, made by photographing an ordinary meter stick. *g*, Magnetic needle. *h*, Wire for charging the gold-leaf electroscope and for supporting the magnetic needle which may be brought into contact with the metallic strip (*i*) by the influence of an ordinary magnet without the apparatus. *i*, Insulated metal strip supporting the gold leaf. *j*, Stopcock for opening or closing the measuring chamber. *k*, Dish containing phosphorus pentaoxide. L, Charging apparatus. *m*, Five or ten accumulators. *n*, Charging point. O, Incandescent light for illuminating the scale. P, Reading telescope. Q, Receptacle for the solution of the substance to be investigated. R, Bulb with a valve. S, Calcium chloride drying tube. T and U, Pressure equalizers.

COMMERCIAL UTILIZATION OF SOME PHILIPPINE OIL-BEARING SEEDS: PRELIMINARY PAPER.

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INTRODUCTION.

The coconut is the best known and most widely distributed oil-producing seed of all tropical or semitropical countries and it is the only representative of its class that has assumed any commercial importance in the Philippines. However, a number of wild or semicultivated plants are found here which help to meet the local demand for vegetable oils, in the various uses to which oils are usually applied. Many of these oil seeds and nuts, or the oils which may be extracted therefrom, probably would find a ready market for use in some form if they were produced in commercial quantities and the uses for which they are best suited determined; therefore, it appeared well worth the trouble to examine a number of the local products and to begin extended investigations on the best methods of their commercial utilization. As a careful study of the properties of oils which are to compete with those already in use is necessary, such a work obviously must be one which will occupy a fairly long period of time. This paper will give a few preliminary observations which later will be extended.

The local use of a given commodity is not always that for which it is best adapted. In the case of fatty oils, questions of expediency rather than suitability usually govern their local application. Many vegetable oils and fats are employed as food and for illumination, when it is evident that they are much better suited for other purposes; furthermore, the valuable therapeutic properties claimed for certain of these products remains to be determined.

VEGETABLE OILS.

PRINCIPAL USES.

The following classification of oils, based on their leading practical uses, is adopted from C. R. Alder Wright.[1] The first and most important is alimental, including the expression or extraction of cooking fats and oils, the addition of oils as food preservatives, and the manufacture of edible products. Formerly, and more particularly in temperate climates, animal fats and oils, such as lard, suet, butter fat, etc., were almost exclusively employed, but within comparatively recent times vegetable oils and fats have come into more general use for the above purposes. In some cases a taste for the new products must be created before they are generally adopted, but there seems to be no question as to the ease with which they are digested or as to their relative nutrient value.

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[1] Fixed Oils, Fats, Butters and Waxes, Lond. (1903), 359.

The second use of oils is for illumination; that is, for burning in lamps and for candle making. Excepting in remote places where petroleum products are excluded because of their greater cost, the introduction of hydrocarbon oils for illumination and fuel has practically superseded the use of those from vegetable or animal fats. According to Tavera[2] a great variety of vegetable oils is used throughout India and the Philippines for lighting purposes, and the latter observation may be confirmed by anyone traveling in the provinces of the Philippines.

The third great application of oils is for soap manufacture. Most vegetable oils are well adapted to this purpose and have long been employed in the soap industry. Those most largely used are palm-nut, coconut, olive, cotton-seed, linseed and castor oils.

The fourth use is for the manufacture of paints, varnishes, linoleum, printers' inks, etc., and for this purpose linseed, certain nut oils, and Chinese wood oil (tüng oil) are employed.

Fifthly, there are miscellaneous applications in the arts and trades, these include lubricants, leather, cloth and textile dressings, employment in textile dyeing and in making printing inks, in the manufacture of perfumes, sealing wax, fly paper and other minor articles.

A partial list of Philippine oil seeds.[3]

Botanical name.	English name.	Local name.
1. *Aleurites moluccana* Willd.	Candle nut	Lumbang or lumbang bato (T.).
trisperma Blanco		Lumbang banucalag (T.).
2. *Calophyllum inophyllum* L.		Palo maria de la playa (Sp.); dinkalan (T.); bitaog (V.).
wallichianum Pl. et Tr.		Palo maria del monte (Sp.); bitanhol (T.).
3. *Ceiba pentandra* (L) Gaertn.	Tree cotton	Kapok (D.); boboy (T.); doldol (V.).
4. *Entada scandens* (L) Benth.	Gilla nuts	Gogo (T.); balogo (P. and V.).
5. *Pongamia glabra* Vent.		Balik-balik (T.); butog (V.).
6. *Anacardium occidentale* L.	Cashew nut	Kasuy (T.).
7. *Caesalpinia bonducella* (L.) Flem.	Fever nut; bonduc seeds (Indo-Eng.).	Kalambibit (T.); dalugdug (V.).
8. *Jatropha curcas* L.	Physic nut; curcus oil	Tuba (T.); kasla (V.); tañgantañgan (P.).
9. *Sesamum indicum* L.	Sesame	Liñga (T.); loga (V.); lagos (P.).
10. *Ricinus communis* L.	Castor bean	Tañgantañgan (P. and T.).

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[2] Medicinal Plants of the Philippines, Manila (1901).

[3] T.=Tagalog; Sp.=Spanish; V.=Visayan; P.=Pam̃panga; D.=Dutch.

DESCRIPTION AND LOCAL USES.

Aleurites moluccana.—This is locally known as *lumbang* or *lumbang bato* in Tagalog, meaning stony fruit, and it is identical with the English candle nut. A very common, large tree, cultivated throughout most of the Archipelago, but more especially in Laguna, Cavite, Tayabas, and Batangas Provinces. It is found scattered in the Provinces of Pampanga and Tarlac, but is unknown in Bataan and Zambales. The supply of this nut is greater than the present demand and frequently the trees are cut for firewood which, because of its resinous quality, is highly prized. The wood is also marketed in Manila for match timber. The tree bears a large, fleshy fruit containing two very hard-shelled seeds which resemble a fairly large hickory nut in size and appearance.

Distribution.[4]—"Everywhere in Oceanica and the Sandwich Islands, and also cultivated in India, South America, West Indies, etc. In the Sandwich Islands the manufacture of candle-nut oil is a considerable branch of industry, about 10,000 barrels being annually exported to Peru, Valparaiso, Mexico, California and New York." The seed yields from 60 to 65 per cent of oil by extraction with carbon bisulphide, ether or chloroform, and about 55 per cent by hydraulic expression at 500 kilos per square centimeter.

Semler [5] describes the candle nut as follows:

> "A product of *Aleurites moluccana*, a tree which like the croton tree belongs to the family *Euphorbiaceæ*. Formerly the *Aleurites triloba* was understood to be a distinct species because of its three-lobed leaves, but all transitions from not lobed to lobed leaves are found on the same tree. *Habitat:* It stretches from the South Sea islands over the Malay Archipelago over India and Madagascar. It appears to live in heavy stands in the forests. It is abundant at 800 meters (2,650 feet) but disappears at 1,200 meters elevation. Its roundish fruits are about the size of a small apple and are contained in a thick, fleshy scale, containing one or two hard seeds about the size of a horse-chestnut. The fruit in its rough state is a purge. When it is roasted it loses its purging properties. Contains 60 to 66 per cent oil. When cold pressed the oil is colorless and of agreeable odor and taste. When hot pressed it is brown and of a disagreeable taste. It has for a long time been known as a drying oil.
>
> "The natives of the South Sea islands roast the fruit out of the shell. The oil is used for lights and for painting. The pressed cake is mixed with water and put around trees to drive away insects."

Philippine candle nut.—One kilo of whole nuts from Cavite Province contained 660 grams of shell, and 340 grams of kernels, or 66 and 34 per cent of shell and kernel, respectively.

One kilo of whole nuts crushed and ground in an oil mill and cold pressed yielded 175.7 grams of light, clear oil, which equals 17.57 per cent calculated on the gross weight of kernels and shells. Calculated on the kernels alone the yield is 51.67 per cent. The physical and chemical constants of lumbang oil are given in Table II.

By far the most general local use made of lumbang oil is for painting bancas (canoes) and for treating timber intended for use in the water, as it is thought to preserve such timber from the attacks of insects in addition to possessing decided drying properties. Practically all of the oil thus used is prepared and marketed in Manila. There are only a few places in the city where the oil is being expressed and the presses used are of the crudest description, consisting of blocks and wedges. I would estimate that each mill produces approximately 20 gallons of oil per month. This oil is sold in 5-gallon petroleum cans and brings one peso ($0.50, United States currency) per gallon.

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[4] Brant, W. T.: Animal and Vegetable Fats and Oils, Phil. (1896), 2, 1.

[5] *Trop. Agr.* (1903), 2, 517.

The cold-pressed oil is of a light, amber color and of an agreeable odor and taste, but we do not know that it is used as food anywhere in the Philippines, although it is reported to be employed in the adulteration of coconut and olive oils here and elsewhere. However, this may readily be detected by the increased specific gravity of the sophisticated oil, if the adulterant is added to any appreciable extent.

Mr. Walker, of this laboratory, has worked out an approximate method for detecting its presence in coconut oil by the decreased solubility of the mixture in absolute alcohol, as follows:

Alcohol used=0.8025 specific gravity at 15.5° C.=0.7938 specific gravity at 26° C., about 98 per cent by volume.

Take 10 cubic centimeters oil and 30 cubic centimeters alcohol in a large test tube. Shake well and place in a water bath at about 90° until dissolved. The mixture should be stirred rapidly with a light thermometer to prevent globules of oil from settling to the bottom. Remove from bath and note the temperature at which oil begins to separate. The end point is when the liquid clouds sufficiently so that the thermometer can not be read when it is in the center of the tube.

TABLE I.—*Test for lumbang oil in coconut oil.*

Coconut oil.	Lumbang oil.	Temperature.
Cubic cm.	*Cubic cm.*	*C.*
10	0	41
9	1	44
8	2	47
7	3	50
6	4	54
5	5	56
4	6	59
3	7	62
2	8	64
1	9	67
0	10	69

This table gives only a rough approximation of the percentage of adulteration. A very pure, fresh coconut oil may read 44° C. or higher, but it may easily be distinguished from an adulterated oil by its light color, pleasant taste and odor. Another sample of lumbang examined read 79° C., which indicates that comparatively large variations from this table may be expected.

Aleurites trisperma.—Another species of candle nut, called *lumbang banucalag* in Cavite and *baguilumbang* in Tayabas, is entirely confined to the Philippines, where it is widely distributed, but not so abundant as the first variety. The tree is about 40 feet high, and the fruit matures in June and July. Both species are propagated by seed or by cuttings and are of very rapid growth. The oil expressed from the *Aleurites trisperma* is more viscous and darker colored than that from *Aleurites moluccana.* Locally it is used principally for painting boats. The seeds of this variety of candle nut are comparatively thin shelled and are easily crushed.

One kilo of unshelled nuts produced 357 grams of shells and 643 grams of kernels. One kilo of unshelled nuts, crushed and pressed, yielded 327.28 grams of oil or 32.72 per cent which corresponds to a yield of 50.9 per cent calculated on the kernels. The oil dries more rapidly than linseed oil or the lumbang bato previously described, and is so closely allied to the Chinese wood oil as to make its differentiation difficult.

A careful study of the drying properties of the two species of *Aleurites* oils found in the Philippines as compared with Chinese wood or tüng oil (*Aleurites* sp.) and linseed oil, is now being made in this laboratory. Considerable confusion and great variation in the recorded constants for the Chinese variety of *Aleurites* exist in the literature.[6] Certain observers name two varieties of trees producing Chinese wood or *tüng* oil and as this oil is considered of great value in the manufacture of varnishes and linoleum, the study which we have undertaken for the establishment of its similarity or identity with the oils furnished by the local species is important. The results are not ready for publication.

TABLE II.—*Table of oil constants.*

Property.	Lumbang bato (*Aleurites moluccana*).	Lumbang banucalag (*Aleurites trisperma*).	Chinese wood[c] or tüng oil (*Aleurites* sp.).	Linseed[d] oil.
Specific gravity at 15° C	0.925–0.927	0.9368	0.9425	0.9368
Acid value (milligrams of potash per one gram of oil)	2.115	2.150	4.547 4.568	3.18
Saponification value (milligrams of potash per one gram of oil)	193.5	200.3 200.5	189.3	186
Iodine value (Hanus)	[a]150.2	[b]158.5	155.7	179
Maumené value	100	86.2	105	103
Refractive index at 60° C	1.4648	1.483	1.5032	1.4687
Hehner value	95.54	95.79	94.32	94.43
Melting point	−12° C.	2 to 4° C.	2° C.	
Solidifying point	−22° C.	−6.5° C.	−7.5° C.	−25° C.

[a] Average 8 determinations.
[b] Average 4 determinations.
[c] Oil obtained on the Hongkong market.
[d] Pure oil obtained from expression of hand-picked seed.

[6] *Kew. Bull.* (1906), 117; *Bull. Imp. Inst.* (1907), **5**, 134.

Calophyllum inophyllum (*Palo maria*).[7]—A large, hardwood tree belonging to the family *Guttiferæ,* found along the sea shores throughout the tropics of both hemispheres. In the Philippines it is known as *palo maria de la playa* to distinguish it from *Calophyllum wallichianum,* the widely distributed form found in upland forests known as *palo maria del monte.* It has a beautiful, dark green, thick, fine-nerved leaf, 4 to 5 inches long, from whence is derived the name *Calophyllum* or *Schönblatt.* The fruit is the size of a walnut, with a fleshy rim containing a thin-shelled seed which incloses a hard, oily kernel. The fruit of the mountain variety is only two-thirds to three-fourths the size of that growing near the seashore. Each tree yields several bushels of nuts per year. There is no established industry, although in some localities the oil is expressed and used for lights.

Oil from the expressed seeds of *Calophyllum inophyllum* is called domba, and in Indo-English, improperly, laurel-nut oil. The kernels on extraction yield 70 to 75 per cent of a greenish-yellow oil. The oil is not servicable as an edible fat, since it contains a poisonous resin to which the color and odor are due. On the other hand, it finds application as a natural remedy in skin diseases and rheumatism, and it is used for that purpose in many districts of India; it is exported in considerable amounts from Travancore, particularly from Burma, and under the name of "udiloöl" it has been experimentated with in Europe for some time in the treatment of rheumatism.

"The seeds of *Calophyllum inophyllum*,[8] a forest tree widely distributed in the eastern tropics, furnish an oil known by various names (dilo, domba, pinnay, poon seed or tamanu oil); when mixed with pigments, this forms a paint that dries in twelve hours, without any previous boiling. Owing to the large yield of oil and the plentifulness of the trees in India, Ceylon, the Malay Archipelago and Java, and the South Pacific islands, etc., this oil appears likely to be an important article in the future."

"Domba oil[9] is obtained from the nuts of *Calophyllum inophyllum.* It is chiefly used as an embrocation for rheumatism, and for illuminating purposes. Domba oil is sold in Burma at four times the Calcutta price of castor oil, which it resembles." G. Fenler[10] has made a chemical examination of the oil from *Calophyllum inophyllum.* He describes it as greenish-yellow in color, of a bitter, pungent taste, soluble in all proportions in the usual solvents, but insoluble in absolute alcohol. The following values are recorded:

Specific gravity at 15° C.	0.942
Reichert Meissel number	.13
Acid value	28.45
Saponification value	196
Iodine value	92.8

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[7] Tavera: Medicinal Plants of the Philippines, Manila (1901), 38.

[8] Alder Wright, C. R.: Fixed oils, fats, butters and waxes (1903), 348.

[9] *J. Soc. Chem. Ind.* (1901), **20,** 624.

[10] *Chem. Ztschr.* (1905), 29, 15.

By treating with caustic soda the oil yields a greenish resin of semiliquid consistency, soluble in alcohol. The fatty acids consist mainly of palmitic, oleic and stearic. It is stated that the oil is also used in the manufacture of soap.

Ceiba pentandra (*kapok.*)—The cotton tree which furnishes the fiber used commercially for upholstering, under the Malayan name "kapok," is exceedingly common in cultivation along the highways, in all parts of the Philippine Islands. It is a somewhat thorny tree 40 to 60 feet high, with horizontal branches in whorls. The fruit is a pod 4 to 6 inches long, spindle shaped and filled with black seeds embedded in fine, silky hairs.

It is distributed throughout the tropics of the world. In Java a considerable industry exists in the products of this tree. The seed hairs are used for pillows, mattresses, sofas, etc., where their lightness, softness, elasticity and immunity from moths, makes them superior for the above-mentioned purposes. In Manila it is being used with excellent results for insulation.

The undecorticated seeds by extraction with ether yield 25.3 per cent of bland oil of a yellowish color and agreeable taste, and 20 per cent by a pressure of 450 atmospheres with the laboratory hydraulic press. Undecorticated, ground seeds are too difficult to press and the yield of oil is too low for economical milling.

The fertilizer analysis of extracted kapok seed meal which is given in Table III compares very favorably with the average composition of upland cotton-seed meal, which is used so extensively in the Southern States of North America. Experiments in feeding ground kapok seed to hogs, cattle and horses at the experimental station of the Philippine Bureau of Agriculture were favorable to its use as a stock food. The product much resembles ground linseed in food value.

The recorded physical and chemical constants of kapok oil are as follows:[11]

Specific gravity at 15° C.	0.9237
Saponification value	181
Iodine value	117.9
Hehner value	94.9
Maumené test	95
Refractive index	51.3°

Anacardium occidentale.—This plant furnishes the *cashew nut* and is very common throughout the Archipelago, having been introduced from tropical America. The nut is a large, yellow, pear-shaped fruit, and contains a brown, kidney-shaped seed attached to one end of the fleshy part. Both the fruit and nut are edible, the latter, when roasted, having a very agreeable taste. The roasted kernel is said to be used in the adulteration of chocolate. The expressed kernel yields a sweet, yellowish oil. The nuts may be obtained in quantities in nearly all Philippine market places.

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[11] Lewkowitsch, J.: Oele, Fette und Wachse, Braunshweig (1905), **2**, **94**.

Jatropha curcas.—A shrubby tree 8 to 10 feet high, common throughout the Philippines, having been introduced from Mexico; it is cultivated for hedges in the towns and along the roadways. The seeds of this plant in shape and size are similar to a large, ground-nut kernel and yield from 30 to 40 per cent of a yellow oil. These seeds are called purging or physic nuts by the English and the expressed oil is the well-known curcas oil of commerce. According to Tavera[12] the oil is used for purposes of illumination in some parts of the Philippines and is exported to Europe to adulterate soaps and candles.

A recent examination of purging nuts from Lagos[13] gave the following results:

> "The kernels constitute 66 per cent of the whole weight of the seeds. Extraction with ether of the desiccated seeds yields 52 per cent of a yellow oil of a faint, peculiar odor and a bland, nutty taste. The oil furnishes the following constants:"

Specific gravity at 15° C.	0.919
Free acid value	4.47
Free acid calculated as oleïc acid	2.25
Saponification value	204
Iodine value	99.1
Ester value	199.5
Neutral oil	97.76

Curcas oil has been examined previously by several observers whose results vary within limits given in the following table:

Specific gravity	0.919–0.925
Free fatty acids (calculated as oleïc acid), per cent	.36–11.8
Saponification value	192–210
Iodine value	98–110

This oil belongs to the class of semidrying oils. It is employed in the manufacture of soaps and candles and also as an illuminant and lubricant, but because of its drying properties it is not well adapted for the last-mentioned purpose. It is a strong purgative and in India it is used medicinally.

Physic nuts examined in the laboratory gave 45 per cent of hulls and 55 per cent of kernels, the latter yielded by extraction with chloroform 63.05 per cent of oil, which corresponds to 34.65 per cent calculated on undecorticated seeds. Because of its purgative action the seed cake left after expression of the oil would be unsuitable as a cattle food. Its fertilizer value is given in Table III.

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[12] Medicinal Plants of the Philippines, Manila (1901), 216.

[13] *Bull. Imp. Inst.* (1904), 2, 170.

Sesamum indicum.—The black-seeded variety has been grown as a minor crop for many years in these Islands; the white-seeded, which produces a finer grade of oil, is found only where it was introduced by W. S. Lyons[14] of the Philippine Bureau of Agriculture. He reports very favorably on the possibility of culture in these Islands of this important oil-bearing seed.

Ricinus communis (castor-oil plant).—A weed universally distributed throughout the tropics of the world and more or less cultivated in temperate and subtemperate regions. It grows in waste places in and about towns throughout the Philippines, apparently seed producing throughout the entire year. This plant is entirely naturalized and grows wild in the Islands, although it is occasionally cutivated for ornamental purposes. In the provinces it is used medicinally, two or three plants frequently being found near the nipa houses of the poorer classes. It is not cultivated here on a commercial scale, the castor oil used in Manila and the larger towns apparently being imported from Europe. The plant thrives without cultivation in poor soils and is one of the commonest and most widely distributed species found in the Philippines, having been introduced by way of the Malayan region probably long before the Spanish conquest. The original home of the species presumably is Africa.

I can find no data regarding the methods of gathering the crop, but it is presumed that the capsules are picked by hand from time to time, as the seeds ripen throughout the year.

The following notes are abstracted concerning the castor-oil industry, from data compiled by Dougherty[15] of the United States Bureau of Statistics:

> First and most important is its use in connection with calico dyeing and printing, in the preparation of so-called "turkey-red oil" which is sulphuretted castor oil, a product soluble in water, possessing the important property of fixing aniline dyes. The second and probably the next most important channel of consumption is the drug trade. It is used in China as a cooking grease, as lard is used in America. It is used extensively in British India and other countries as an illuminant. Australia imported 769,000 gallons in 1898 and Cape of Good Hope 307,000 gallons in 1902 for the same purpose. The peculiar properties of this oil, which is heavy, viscous and non-drying, adapt it for lubrication purposes, as is well known. Heavy petroleum is used more extensively only on account of its greater cheapness. Its value as a lubricant is suggested by the fact that petroleum products adulterated with resin are now sold under the name "machine castor oil." Castor oil also has properties that adapt it as a leather dressing. Many minor uses may be mentioned such as its employment in the manufacture of sticky fly paper, and so-called "glycerine soap."
>
> *Process of manufacture.*—The equipment for a castor-oil mill is identical in its main features with that of mills for the manufacture of linseed, cotton-seed,

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[14] Farmers' Bull. (1903), No. 7, 12.

[15] Year Book, U. S. Dept. Agr. (1905), 287.

or coconut oil; that is, the mechanical unit of production is the hydraulic press. Hulling and crushing the seeds is unnecessary. They are hand picked and submitted to hydraulic pressure either hot or cold. Two grades of oil are produced, the first for medicinal use, and the second for the various other purposes. One-half to one cent per pound difference in price exists between the two grades, 9 to 11 cents per pound being the prevailing price in the United States. The oil cake. called castor pomace, on account of its poisonous properties, has no food value, but it contains potash and phosporic acid, and is especially rich in nitrogen, therefore it is well adapted for a manurial. The high percentage of oil left in oil cake by commercial processes is said to prevent its rapid decomposition in the soil and thus to prolong its fertilizing effect. In some sections of the United States the castor pomace is highly regarded as a fertilizer for tobacco. In British India, where more of this product is made and used than in any other country in the world, it is much esteemed as a manure for potatoes, wheat, oats and corn. Good qualities of beans contain about 45 per cent of oil, but the yield extracted by manufacturing processes in the United States approximates only about 32 per cent. At this rate there is obtained 16 pounds (2 gallons) of oil and 34 pounds of pomace per bushel of 50 pounds of the beans.

The supply of the United States is almost entirely derived from two widely separated regions: the first, a few counties in Oklohama, Kansas, Missouri and Illinois, the second, British India, a country that has long held the monopoly of the commercial castor bean production of the world. Statistics show that probably three-fourths, and possibly four-fifths, of the castor oil manufactured in the United States is from imported beans. The maximum demand for this product in the United States is 1,000,000 gallons annually in round numbers.

British India is the only great castor bean producing country, the United States, England, France and Germany all deriving their supply from this particular source. The castor bean production in the United States has declined steadily for years, while the demand for its products has had a steady upward trend until, as above stated, practically the entire supply is now imported. Several reasons for this condition of things may be given. The castor plant being tropical in its origin must be acclimated in a country of late and early frosts, to which the plant is very susceptible, while the land is much more valuable for the growing or crops already adapted to the prevailing climatic conditions.

In the Philippine Islands we find the plant producing abundantly under natural conditions, therefore much may be accomplished under proper cultivation. Furthermore, any initial outlay in milling machinery would be unnecessary, as the product can be worked up in a coconut-oil mill. We might therefore be able to place on this market an oil for purposes of lubrication and illumination which would be nonedible and which could be produced as cheaply as coconut oil, now in general use. We are nearer to the Australian market than is British India, from whence the supply of castor oil is brought, but most important of all if we could supply the increasing demands of America and thus divert the large export trade from British India to the Philippine Islands, the result would warrant the exploitation of castor oil in the Archipelago.

TABLE III.—*Comparison of the fertilization value of some Philippine seed cakes with that of cotton-seed meal.*

	Lumbang bato.	Lumbang banucalag.	Kapok.	Castor.	Palo maria.	Cotton seed.	Physic nut.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	8.189	8.480	13.67	8.64	6.248	7.50	9.91
Total nitrogen	6.464	3.968	5.21	4.80	2.68	6.37	2.14
Nitrogen equivalent to ammonia	7.852	4.818	6.326	5.83	3.254	7.75	2.60
Total phosphoric acid	3.355	2.292	2.798	1.75	1.006	2.65	1.33
Available phosphoric acid	3.280	2.183	2.741	1.55	.964	2.45	1.25
Potash soluble in water	1.502	1.311	1.758	1.04	1.00	1.55	2.42
Relative commercial value per ton of 2,000 pounds[a]	$27.67	$17.51	$24.61	$19.77	$13.83	$26.76	$11.22

[a] The valuation is based on the average market quotation on the unmixed ingredients used in the manufacture of commercial fertilizers.

ERRATA.

Page 310 for **Osmoteron** read **Osmotreron.**
Page 342 for **faciolata** read **fasciolata.**

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(New generic, specific, and subspecific names are printed in **heavy-faced** type.)

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